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Assessing Malaysia Marine Fisheries Sustainability Under Climate Change Pressure: A Quintuple Helix Approach

Mohamad M. Fikri[1*], Siti Rahyla Rahmat[2], Saidatulakmal Mohd[3]

[1]School of Social Sciences, Universiti Sains Malaysia, 11800 Pulau Pinang, Malaysia;
Faculty of Business, Economics and Social Development, Universiti Malaysia Terengganu, 21030 Kuala Nerus, Terengganu, Malaysia.
Email: fikri@umt.edu.my
[2]School of Social Sciences, Universiti Sains Malaysia, 11800 Pulau Pinang, Malaysia.
Email: rahyla@usm.my
[3]School of Social Sciences, Universiti Sains Malaysia, 11800 Pulau Pinang, Malaysia.
Email: eieydda@usm.my

CORRESPONDING AUTHOR (*):
Mohamad M. Fikri
(fikri@umt,edu.my)

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ABSTRACT

Marine fisheries are a major industry in Malaysia fisheries sector, which contributes significant growth in the economy and national food security. Unfortunately, this industry is vulnerable to the threats of climate change in relation to the marine environment such as the rising sea level, water acidity, and sea surface temperature. This study aims to assess the impact of climate change on the sustainability of marine fisheries in Malaysia. This study uses Quintuple Helix model approach which is the expansion of the established Triple Helix sustainability model that includes climate change as one of the important indicators. It involves a time-series analysis from 1989 to 2018 using Auto-Regressive Distribution Lag (ARDL). A long and short-run impact from rising in temperature and sea level on marine fisheries sustainability will help to impose a better adaptation and mitigation strategy for this industry. Consequently, the sustainability of marine fisheries will secure national economic prosperity and healthy protein supply.

Contribution/Originality: This study give a comprehensive knowledge on long-run and short-run relationship between the sustainability variables of marine fisheries through the quintuple helix approach.

1. Introduction

Marine fisheries are a major industry in Malaysia fisheries sector, followed by aquaculture and inland fisheries (Department of Fisheries Malaysia [DOF], 2019). In 2017, a sum of 1.46 million metric tonnes of fish landed which contributed to 8.8 percent of the total landing of marine fisheries in South-East Asia (Southeast Asian Fisheries Development Center [SEAFDEC], 2017). The marine resources are important in providing a healthy source of animal protein, minerals, and various essential nutrients (Avadí & Fréon, 2015; Tran et al., 2018). However, this marine resources are vulnerable to many threats such as

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natural death of fish and overfishing (Diop et al., 2018). It has resulted in unstable marine landing in Malaysia since 1990 (DOF, 2019). This situation is consistent with the world's marine fisheries landing that has been reported to be static since 1980 (Food and Agriculture Organization of The United Nations [FAO], 2018). The situation is getting critical with the existence of climate change. According to Tang (2019), marine resources, ocean and coastal resources are among seven sectors in Malaysia that are vulnerable to climate change. In 2016, Malaysia recorded the highest temperature (39.3 degree Celsius) and experienced Super El Nino phenomenon that caused drought throughout country (Malaysian Meteorological Department [MET], 2016). This has resulted in the rise in sea surface temperature and acidity as well as changes in the ecosystem and biology (Badjeck, Allison, Halls, & Dulvy, 2010; Pörtner & Peck, 2010).

As a result, there are changes in the pattern of fisheries distribution (Merino et al., 2012) that put more pressure on marine fisheries sustainability. Therefore, it is vital to identify the critical factors that influence the national marine fisheries landing. The effect of climate change in Malaysia between 1971 to 2018 can be observed from the increase in mean daily temperature, sea level, and extreme weather phenomena (Tang, 2019). Besides that, according to the special report by the Intergovernmental Panel on Climate Change (IPCC), Malaysia will also receive the impact of the increase in global temperature by 1.5 degree Celsius (Pereira, 2018). If the climate change effect continues, the fishing effort will be affected and there will be a reduction in fisheries stock (Belhabib, Lam, & Cheung, 2016). This poses a threat to the sustainability of marine fisheries industry and consequently threatens national food security. Thus, this study aims to assess the impact of climate change on the sustainability of marine fisheries in Malaysia by using Quintuple Helix approach. The following section will discuss the development of Quintuple Helix of Marine Fisheries Sustainability, methodology, result and discussion, as well as conclusion.

2. Climate Change and Marine Fisheries Sustainability

The sustainability of marine fisheries is significant to the survival of the world's food supply (Voss et al., 2019) as a source of animal protein, minerals, and various important nutrients (Avadí & Fréon, 2015; Tran et al., 2018). An estimated 500 million people worldwide depend on marine fisheries resources for economic and social development (Thiao & Laloë, 2012; Voss et al., 2019). As a result, these marine fisheries resources face various ongoing crises and most of these resources have been obtained unsustainably (Aguado, Segado, & Pitcher, 2016). Studies by Sumaila and Tai (2020), Teh, Cheung, Christensen and Sumaila (2017), Schuhbauer, Chuenpagdee, Cheung, Greer, and Sumaila (2017) and Cheung et al. (2013) found that marine fisheries resources have experienced depletion due to excessive fishing activities. This situation will negatively impact the marine biodiversity and the ecosystem, further threatening the sustainability of marine fisheries resources.

Teh et al. (2017) also stated that until 2017, more than 550 marine fish and invertebrate species are listed on the IUCN Red List as critically endangered, endangered, and vulnerable. This finding are also in line with a study by Pomeroy, Parks, Courtney and Mattich (2016), who found that overfishing has caused coastal areas in Southeast Asia to experience a decline in the quantity of fish. However, marine ecosystems have the potential to recover if the level of exploitation is significantly reduced (Teh et al., 2017).

Apart from fishing activities by humans, climate change also threatens the sustainability of marine fisheries. Climate change affects the distribution of fish species because of

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changes in ocean habitats. At the same time, climate change also disrupts the physical, chemical, and ecological environment of the ocean (Sumaila & Tai, 2020; Teh et al., 2017) which ultimately leads to the deterioration of marine ecosystems. Studies of the impacts of climate change from various perspectives and locations have shown significant effects. Natural disasters linked to climate change occur all over the world and leave their impacts on various sectors including marine fisheries (Tang, 2019). This study by Tang (2019) is also supported by Das et al. (2020), Bhuiyan et al. (2018), Raj et al. (2016) and Barange et al. (2014) who found that there is a reduction in catches and a decline in biodiversity at the global level. Climate change has affected the oceans and marine fisheries such as sea level rise, sea water temperature, acidity and oxygen reduction (Ami Hassan et al., 2017; Raj et al., 2016; Talloni-Álvarez et al., 2019). In addition, Alnafissa et al., (2021) found that wind speed and storms (Heck, Beck, & Reguero, 2021) also affect and threaten marine fisheries.

The increase in sea temperature due to climate change has threatened the growth and fertility of marine ecology (Chandrapavan, Caputi, & Kangas, 2019) in addition to affecting the habitat of marine life (Hu et al., 2022; Pawluk et al., 2021; Walden et al., 2019; Mcclenachan et al., 2019). A study by Chandrapavan et al. (2019) on blue crab species in Western Australian waters found that the natural mortality rate of this species has increased due to sea water heat waves. Indirectly, this has also affected the catch of local fishermen. In addition, the crab breeding cycle has also changed and affected the catch period (Chandrapavan et al., 2019).

While the studies by Hu et al. (2022), Pawluk et al. (2021); Walden et al., (2019) and Mcclenachan et al. (2019) on marine habitat changes as a result of increasing sea water temperature found disruption to habitats and species migration. As many as nine fish species are predicted to experience habitat reduction and as many as 20 fish species will move to other areas by the year 2050 (Hu et al., 2022). A study in the North East Atlantic Ocean also found that 35 of the 50 marine fish species that are abundant in the North East Atlantic waters have migrated to other areas as a result of changes in sea water temperature (Simpson et al., 2011). Similarly, a study by Liang, Xian, and Pauly (2018) found that as many as 13 new marine species and 25 fish species were found in the Taiwan Strait which were previously only found in the southern part of the South China Sea waters.

Other effects of rising sea levels are also proven by studies by Silvana (2017) and Iris Monnereau and Hazel (2017) who found that access to marine fisheries has become limited due to the rising sea levels and rising sea surface temperatures phenomena. The increase in sea level causes the occurrence of large waves and strong storms thus disrupting the operations as well as the fishing community in ways that limit the access to fishing vessels and fishing areas, restrict the movement of vessels in ports, interfere with fishing equipment, damage vessel motors, affect the catchability of some pelagic species, and impact the post-harvest sector (Iris Monnereau & Hazel, 2017).

In addition, the rising sea level is also seen to have a negative impact on benthic habitats on the coast (Iris Monnereau & Hazel, 2017). The loss of this critical habitat will result in a decline in fish production and eventually reduce the yield of sustainable fisheries, especially fishery species that depend on healthy mangrove and seagrass habitats to grow. Degradation of marine resources as well as excessive capture will make the sustainability of fisheries difficult to achieve.

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Therefore, there is a critical need for a more comprehensive assessment of the sustainability of marine fisheries. The difference in research findings by Ding et al. (2017b) and Sugiawan et al. (2017) regarding the impact of economic and population growth on the sustainability of marine fisheries shows the diversity of vulnerability levels of a marine fishery resource. The effect of economic and population growth shows the importance of these variables for research as well as in the formation of policies, strategies, and governance to achieve the sustainability of marine fisheries. However, there are also other factors influencing marine degradation that need to be considered. For example, a resource management approach that combines economic, social, and environmental aspects in the study of MacDonald and Knudsen (2004) can stimulate the achievement of marine fisheries sustainability. In addition, feedback from the fishing industry that has faced the decline of resources is important in strategizing the effort in achieving sustainability of the country's fisheries.

3. Quintuple Helix of Marine Fisheries Sustainability

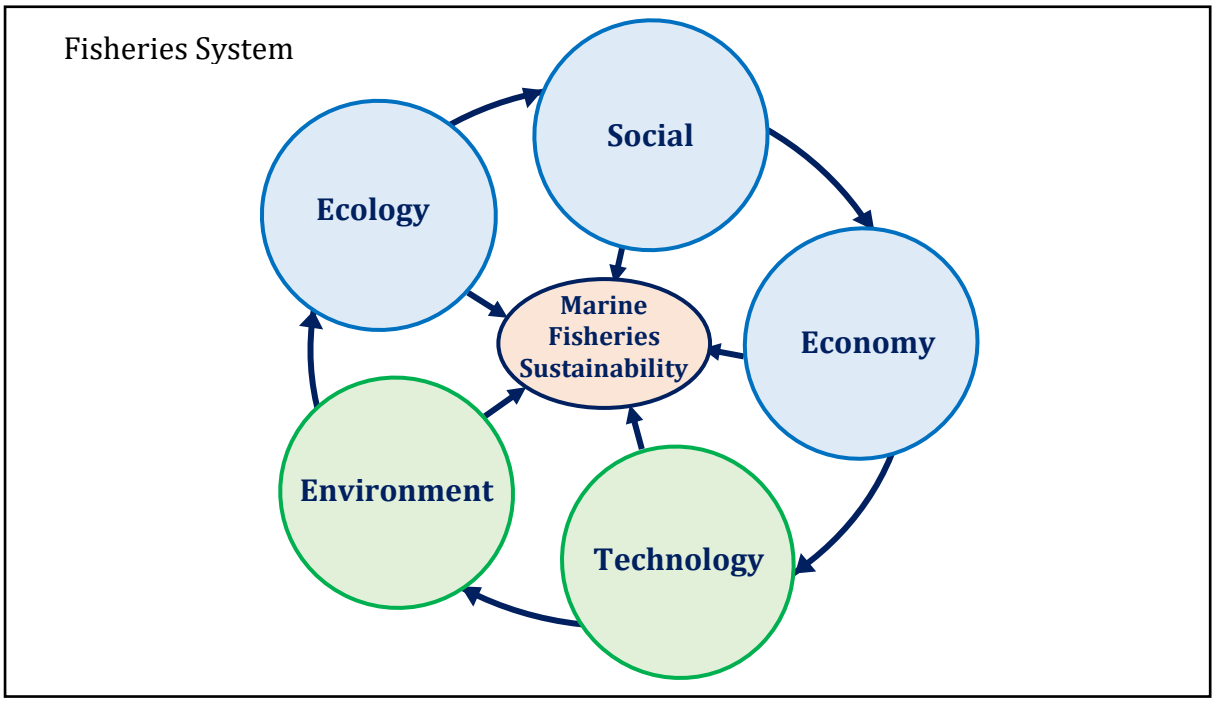
According to Brundtland Commission in 1987, sustainable development is defined as "the development that fulfils the current requirements without compromising future generation's ability" (International Institute for Sustainable Development, n.d.). Classical fishery science stated that fisheries sustainability refers to a sustainable level of captures while ecological economists opined that sustainability is ensuring that the natural capital stock is at the exact or lower level than the current one. There are three dimensions for sustainable development which are generally agreed by researchers - ecology, social, and economy (Aguado et al., 2016). Based on the knowledge or innovation model, the dimensions form a non-linear Triple Helix model which consists of a three-way network and hybrid organization from a university-industry-government relationship. The core of this model is the knowledge-based economy (Carayannis, Barth, & Campbell, 2012).

Next, this innovation model is further developed into Quadruple Helix which is a Triple Helix innovation on the relationship with public community through media or culture. At this stage, Quadruple Helix focuses on the community core and knowledge-based ruling (Carayannis & Campbell, 2010). The innovation of Quadruple Helix of the natural environments forms the Quintuple Helix with a cross-sectional framework and interdisciplinarity towards sustainable development and social ecology. The combination of these five complex helixes consists of science, social science, and humanity field focuses on the socioecological core transition (Carayannis et al., 2012). The natural environment as the fifth helix makes Quintuple Helix a holistic measurement towards sustainable development. Since climate change is an issue in natural environment, Quintuple Helix will affect all helixes through knowledge as well as the latest and the most advanced innovation to achieve sustainable development (Carayannis et al., 2012).

Thus, this study has adopted the Quintuple Helix Innovation Model as the basis of model formation and variables selection. The addition of technology and the environment to the Triple Helix of sustainable development in this study is identified as Quintuple Helix of Marine Fisheries Sustainability. Figure 1 shows the Quintuple Helix of Marine Fisheries Sustainability adapted from Charles (2001) and Carayannis et al. (2012). The original sustainability dimensions were constructed from Natural Ecosystem and Human System components while the additional dimensions were components of the Management System that interact dynamically with each other.

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Figure 1: Quintuple Helix of Marine Fisheries Sustainability



Source: Adapted from Carayannis et al. (2012)

4. Methodology

This study utilised the Auto Regressive Distribution Lag (ARDL) on 30 years' dataset between 1989 to 2018. Six variables are identified as proxies to Quintuple Helix of Marine Fisheries Sustainability as shown in Table 1. These variables are also used by other researches and can be observed in studies conducted by Anneboina and Kavi Kumar (2017), Bhuiyan et al. (2018), Ding, Wang, Chen and Chen, (2017a), Parker et al. (2018) and Sugiawan, Islam, and Managi (2017). The data for marine fisheries landing and the number of vessels were acquired from DOF's annual report. Next, real GDP data were obtained from the World Bank database, population growth from Department of Statistics Malaysia, mean daily temperature from Malaysian Meteorological Department and mean sea level from University of Hawaii Sea Level Center.

Table 1: *Quintuple Helix Variables for* Marine Fisheries Sustainability

Helix	Variables
Ecology	Marine Fisheries Landing (MFL)
Economy	Real GDP (RGDP)
Social	Population Growth Rate (PPG)
Technology	Number of Vessel (NOV)
Environment	Mean Daily Temperature (MDT)
	Mean Sea Level (MSL)

This study began with unit root test to acquire the stationarity for each variable. Using E-Views software, two tests namely Augmented Dickey-Fueller (ADF) and Phillips-Perron (PP) were conducted. The stationary level is vital in avoiding spurious estimator as a result of non-stationary variables. ARDL analyses relationships for data with different stationary levels whether it is at level or first difference.

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The next step was to conduct Bounds Test to obtain long-run and short-run estimators for ARDL model, as follows:

$$\Delta lnMFL_t = \beta_0 + \sum_{j=1}^{k1} \beta_1 \, lnMFL_t + \sum_{j=0}^{k2} \beta_2 lnRGDP_t + \sum_{j=0}^{k3} \beta_3 lnPPG_t + \sum_{j=0}^{k4} \beta_4 lnNOV_t + \sum_{j=0}^{k5} \beta_5 lnMDT_t + \sum_{j=0}^{k6} \beta_6 lnMSL_t + \beta_7 \, lnMFL_{t-1} + \beta_8 lnRGDP_{t-1} + \beta_9 lnPPG_{t-1} + \beta_{10} lnNOV_{t-1} + \beta_{11} lnMDT_{t-1} + \beta_{12} lnMSL_{t-1} + \varepsilon_{t-1}$$

Finally, in order to assess the long-run and short-run relationships stability, Cumulative Sum of Residual Recursive (CUSUM) and Cumulative Sum of Square of Residual Recursive (CUSUMSQ) were conducted.

5. Results and Discussion

The unit root tests result for each variable is shown in Table 2. All variables are stationary at first difference with various significant levels. Only MSL was consistently stationary for both categories at level. MFL, RGDP, and MDT achieved stationary level at multiple Intercept and Trend and Intercept categories. All variables for the constructed ARDL model cointegrate at maximum lag two at one percent of significance level. This model also passed all diagnostic checking i.e. free from normality, serial correlation, and heteroscedasticity, as shown in Table 3.

Table 2: Result of ADF and PP unit root tests

	Variable	ADF unit root test		PP unit root test	
		Intercept	Trend and intercept	Intercept	Trend and intercept
Level	**MFL**	-2.235(1)	-3.755(0)**	-2.545(9)	-3.707(2)**
	RGDP	-2.108(0)	-5.778(6)*	-2.111(1)	-3.084(3)
	PPG	0.660(1)	-3.062(0)	-0.257(0)	-3.062(0)
	NOV	-0.428(0)	-2.598(0)	-0.651(3)	-2.592(2)
	MDT	-2.943(1)***	-2.381(1)	-6.316(3)*	-6.281(2)*
	MSL	-3.578(0)**	-7.970(0)*	-3.980(4)*	-7.082(2)*
First difference	**MFL**	-10.032(0)*	-10.472(0)*	-10.275(1)*	-13.562(4)*
	RGDP	-3.890(6)*	-3.351(6)***	-4.645(2)*	-4.940(1)*
	PPG	-7.398(0)*	-7.787(0)*	-7.398(0)*	-8.494(3)*
	NOV	-4.546(0)*	-4.640(0)*	-4.560(2)*	-4.681(2)*
	MDT	-10.352(0)*	-10.559(0)*	-10.742(2)*	-11.249(3)*
	MSL	-10.418(0)*	-9.927(0)*	-11.146(1)*	-10.579(1)*

Note: 1. *, ** and *** represent 1%, 5% and 10% significance levels, respectively. 2. The optimal lag has been selected using the Schwarz information criterion (SIC) for ADF tests and the bandwidth has been selected using the Newey-West method for the PP test.

Table 3: Result of ARDL cointegration and Diagnostic Checking

Maximum lag	**SIC**	**F Statistic**	
2	**(1, 2, 0, 0, 2, 0)**	**8.618***	
Critical Values for *F*-statistics#		Lower I(0)	Upper I(1)
1%		3.41	4.68
5%		2.62	3.79

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10%		2.26	3.35
Normality	Serial correlation	Heteroscedasticity	
2.541	0.804	1.584	
[0.281]	[0.258]	[0.197]	

Note: 1. The critical values are obtained from Pesaran et al. (2001) based on case III: unrestricted intercept and no trend. 2. *, **, and *** represent 10%, 5% and 1% level of significance, respectively. 3. The numbers in brackets [ ] are p-values.

Long-run and short-run coefficients show that there are significant relationships for all variables as shown in Table 4. For the long-run coefficient, RGDP, PPG, MDT, and MSL demonstrate positive relationship. An increase of one percent on RGDP, PPG, MDT, and MSL shows an increase of 0.36, 0.07, 1.74, and 1.46 percent to MFL. On the other hand, NOV is negatively correlated as an increase of one percent NOV results in a 0.12 percent decrease for MFL. For the short-run coefficient, it is found that PPG and MSL are positively correlated i.e. an increase of one percent PPG and MSL causes an increase of 0.10 and 2.00 percent increase on MFL, respectively. Meanwhile, RGDP and NOV are negatively correlated whereby an increase of RGDP and NOV by one percent causes a drop of MFL by 0.32 and 0.17 percent, respectively. Distinctive from other variables, MDT has short-run relationships at different lags and signs.

Table 4: Long-run and Shot Run Estimation

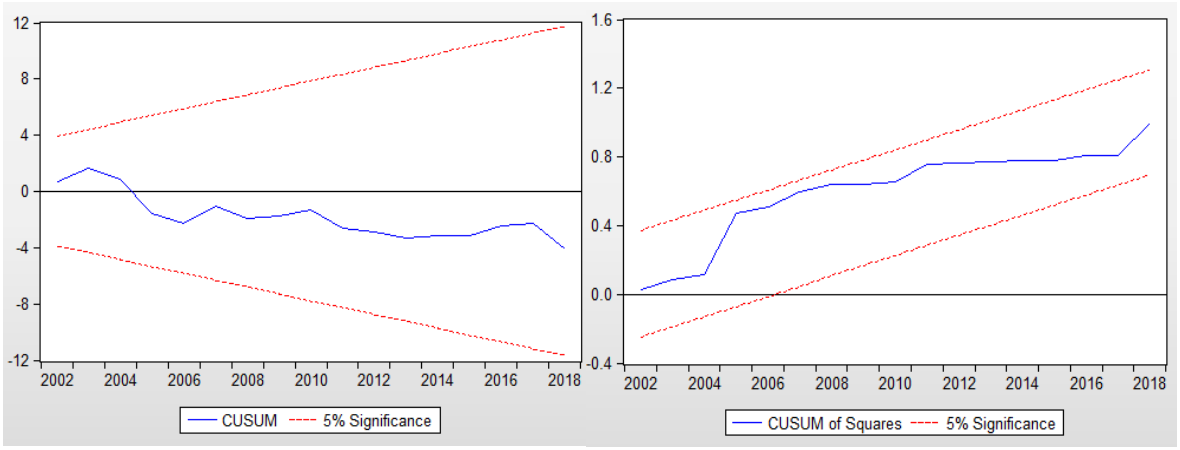
ARDL (1, 2, 0, 0, 2, 0) Criteria: SIC			
Estimation of Long-Run Elasticities		**Estimation of Short-run Restricted Error Correction Model (ECM)**	
Variables	Coefficient	Variables	Coefficient
LNRGDP	0.358*	dLNRGDP	0.077
	(0.029)		(0.150)
LNPPG	0.072**	dLNRGDP (-1)	-0.321**
	(0.034)		(0.141)
LNNOV	-0.121*	dLNPPG	0.099**
	(0.039)		(0.047)
LNMDT	1.740*	dLNNOV	-0.165**
	(0.594)		(0.060)
LNMSL	1.460**	dLNMDT	0.332**
	(0.521)		(0.133)
C	3.270	dLNMDT (-1)	-1.798**
	(1.955)		(0.670)
		dLNMSL	2.001**
			(0.772)
		ecm_{t-1}	-1.370*
			(0.159)

Note: Dependent variables. (*),(**),(***) indicate significant at 10%,5% and 1% significance level respectively. Number in brackets represent standard error.

The error correction model (ecm_{t-1}) for this study is negative and significant at one percent level which subsequently validates the long-run relationship between the variables. The estimator measures the speed of adjustment of a dynamic model at 137 percent. The long-run and short-run coefficients are also stable when there is no line crossing the Bounds line at five percent level. Table 5 shows the stability of mean in CUSUM and variance in CUSUMSQ.

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Table 5: Stability test

CUSUM	CUSUMSQ
	

The analysis found that all variables have significant relationships in the long and short-run. However, this study could not prove that the climate change variable will negatively affect marine fisheries resources. The increase of mean daily temperature only negatively affects in the short-run. In contrast, the increase of mean daily temperature and mean sea level do not negatively affect marine fisheries resources in the long-run. This might be due to the dependency level on marine fisheries resources and other fishery products such as aquaculture (Ding, Chen, Hilborn, & Chen, 2017b).

Technological advancement is found to negatively affect marine fisheries resources in the long-run and short-run consistently. In 2017, there were 52,648 registered boats with various fishing gears according to tonnage class. From that figure, 29 percent were inboard-powered vessels, 66 percent were outboard-powered, and 5 percent were non-powered. The diversity of fishing gear and tonnage class is a threat to marine fisheries resources if these technologies are not managed wisely. Further, the number of vessels has significantly degraded the environment through CO_2 pollution from the fuels used (Parker et al., 2018).

In addition, economic growth will positively affect marine fisheries resources in the long-run as opposed to the effects in the short-run. This finding corroborates the study by Ding et al. (2017a) and Sugiawan et al. (2017) who stated that economic growth, in the long-run, positively affects marine fisheries resources through conservation actions. Population growth does not affect marine fisheries resources in the long-run and short-run. However, the finding has not confirmed previous research by Ding et al. (2017a) and Sugiawan et al. (2017) who found that population growth will increase demands on seafood thus putting stress on marine fisheries resources.

Moreover, the government's awareness in participating in global efforts such as Sustainable Development Goals – SDG contributes to the development of national marine fisheries sustainability. SDG is a universal agenda to end poverty, achieve community prosperity and wellbeing as well as to protect the environment by 2030 (United Nation Development Program [UNDP], 2016a). Among the important SDGs that are directly related to this study are SDG 13 and SDG 14. SDG 13 focuses on the immediate actions to combat climate change and its effect (UNDP, 2016b) while SDG 14 focuses on the

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governance of the sea to conserve and use the world's oceans and marine resources sustainably (Singh et al., 2018; United Nations, 2018).

6. Conclusion

The findings show that population and economic growth, technological advancement, and climate change does have relationships with marine fisheries resources in the long-run. The study used only 30 years of the dataset. Longer terms of data and additional variable on marine climate such sea surface temperature is necessary in to obtain a more accurate relationship between the variables. From the findings, policymakers can consider factors that could be possible threats to marine fisheries resources such as the number of vessels. As a result, the sustainability of marine fisheries will secure national economic prosperity and healthy protein supply.

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Conflict of Interests

The authors reported no conflicts of interest for this work and declare that there is no potential conflict of interest with respect to the research, authorship, or publication of this article.

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