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Impact of Natural Disasters on Biodiversity: Evidence Using Quantile Regression Approach

(Impak Bencana Alam ke atas Kepelbagaian Biologi: Bukti menggunakan Pendekatan Regresi Kuantil)

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ABSTRACT

Biodiversity is vital as it supports major economic activities and employment but it is at risk and is declining rapidly in many parts of the world. This study examines the impact of total natural disasters on the number of endangered species (fish, mammal, bird and plants) for a sample of 110 countries in the year 2015. Ordinary least squares and quantile regression are employed to explain the relationship between occurrences of total disasters and species in danger for these countries. The OLS results suggest that the occurrences of natural disasters exhibit positive relationship with biodiversity loss. Our further analysis using quantile regression study suggest that countries with lower biodiversity loss are more likely to experience decrease of endangered plants with the increasing number of natural disaster occurrences as compared to countries with higher biodiversity loss. These countries will also experience more loss in birds in danger when the population grows. In addition, countries with higher biodiversity loss are more likely to face decrease in threatened birds due to the increase in the percentage of the protected area and income per capita as compared to countries with lower biodiversity loss. However, all the variables have no significance influence on the threatened fish species. Urban population growth effect on threatened mammals is greater at higher quantiles whereas the effect of income per capita is much greater in the countries with higher biodiversity loss but after a certain point, the income per capita decreases with higher biodiversity loss.

Keywords: Biodiversity loss; quantile regression; species

ABSTRAK

Kepelbagaian biologi amat penting kerana ia menyokong aktiviti ekonomi dan merupakan satu sumber pekerjaan yang utama, tetapi ia menghadapi risiko yang amat tinggi dan ia semakin merosot di beberapa negara di dunia. Kajian ini mengkaji kesan bencana alam ke atas bilangan spesies terancam (ikan, mamalia, burung dan tumbuhan) untuk tahun 2015 di 110 negara. Kedua-dua teknik regresi kuasa dua terkecil (OLS) dan regresi kuantil telah digunakan untuk menganggarkan hubungan antara kejadian bencana alam dan spesies terancam untuk 110 negara ini. Keputusan OLS menunjukkan bahawa kejadian bencana alam menunjukkan hubungan positif dengan kehilangan biodiversiti. Analisis yang lebih lanjut dilakukan dengan menggunakan regresi kuantil dan ia menunjukkan bahawa apabila bilangan bencana alam meningkat, negara-negara dengan kehilangan biodiversiti yang lebih rendah lebih berkemungkinan mengalami penurunan tumbuhan terancam berbanding dengan negara-negara yang mengalami kehilangan biodiversiti yang lebih tinggi. Keputusan kajian ini juga menunjukkan bahawa kehilangan burung terancam meningkat dengan perkembangan populasi di negara-negara ini. Selain itu, dengan peningkatan dalam peratusan kawasan dilindungi dan dalam pendapatan per kapita, negara–negara yang mempunyai kehilangan biodiversiti yang tinggi lebih berkemungkinan menghadapi penurunan dalam bilangan burung terancam berbanding dengan negara-negara yang mengalami kehilangan biodiversiti yang lebih rendah. Walau bagaimanapun, semua pemboleh ubah tidak mempunyai pengaruh penting terhadap spesies ikan yang terancam. Pertumbuhan penduduk bandar memberi kesan yang lebih besar pada kuantil yang lebih tinggi bagi mamalia yang diancam. Pendapatan per kapita memberi kesan yang lebih di negara-negara yang mengalami kehilangan biodiversiti yang lebih tinggi tetapi selepas titik tertentu, pendapatan per kapita berkurang dengan kehilangan biodiversiti yang lebih tinggi.

Kata kunci: Kepelbagaian biologi; regresi kuantil; spesies

INTRODUCTION

Due to changes in global climatic environment, natural disasters have calamitous impact on human development and biodiversity (Guha-Sapir & Hoyois 2012; McLellan et al. 2014; Halkos 2011; Strobl 2012; Field 2014). Biodiversity is vital as it supports major economic activities and employment in agricultural, fisheries, forestry, pharmaceuticals, pulp and paper, cosmetics, construction and biotechnology (UNDP 2014). Biodiversity is in jeopardy and is declining rapidly in many parts of the world and among the major drivers of biodiversity loss are the growing world human population, human activities, habitat destruction, degradation, exploitation, climate change and natural disasters (McLellan et al. 2014; Halkos 2011; Visconti et al. 2011). These drivers have contributed to a decrease of 52% of the planet's biodiversity since 1970 (WWF 2014).

The number of mammals, birds, reptiles, amphibians and fish in the planet has dropped by 60% from 1970 to 2014 (WWF 2018). Figure 1 shows that the greatest threats to global biodiversity and function of ecosystems are overexploitation of species, agricultural and land conversion, driven by exploding human consumption (WWF 2018; WWF 2014). Globally, the overall population of animal species has declined; 76% of freshwater wildlife, 39% of marine wildlife and 39% of terrestrial wildlife have been lost since 1970 (McLellan et al. 2014). From the period 1970 to 2010, the greatest loss of biodiversity was in low-income countries. The high-income countries showed an increase of 10% whereas for the middle-income countries, there was a loss of 18% during this period (McLellan et al. 2014).

Due to rapid urbanization, logging and conversion for agriculture, the forest which is vital to sustain natural life cycles and biodiversity is at jeopardy around the world and this have increased the rates of species extinction globally. There is a net loss of 11.5 million hectares of the forest a year since 2000 (Hansen 2013) and from the year 2000 to 2012, Indonesia has the greatest forest loss followed by Paraguay, Malaysia and Cambodia. As a result of deforestation, the global CO2 emission has increased between 4% to 14% and is negatively affecting the climate regulation, water supplies and biodiversity richness (Hsu et al. 2014). The coastal ecosystem such as coral reefs and mangrove forest have been removed to make way for population growth, industrialization and intensification of agriculture that created ecosystem degradation and caused loss in natural protection against cyclones and tsunamis, as demonstrated by the 2004 Tsunami. In South East Asia, 28% of the mangrove forest was removed in the years 1970 to 2000 to accommodate commercial shrimp farming. In addition, during the period 1975 to 2005, 82% of the mangrove forest was loss for agricultural activities (Giri et al. 2015).

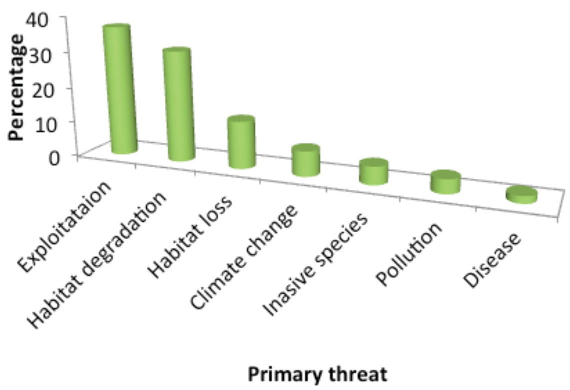

FIGURE 1. Main Threats to the Populations in the LPI (Living Planet Index)

Source: WWF (2014)

Biodiversity loss has a greater impact on the poor than the wealthier people due to the dependency level of the poor on biodiversity and ecosystem services for their livelihoods. 840 million people (70% of the world's poor) live in the rural areas and depend on the ecosystem such as forest, rangelands, rivers, lakes and ocean for their livelihood (World Bank 2014). For example, 350 million were affected by the loss of coral reefs (World Bank 2014) and about 60% of the total Philippine population live in the coastal area and depend on these coastal resources such as coral reefs, sea grass beds, mangrove forest and fisheries for livelihoods (NEDA 2011). However, due to climate change impacts that have increased the sea level and sea surface temperature, the productivity and quality of the country's coastal resources has declined and this has a major effect on the income of these households.

Not only do natural disasters trigger enormous damage to the environment and human development but degraded environments and climate change can also aggravate disaster impacts (UNEP 2009). Forest and oceans are considered carbon sinks as they can absorb and accumulate carbon over a long period of time. The world's forest ecosystems stores about 289 gigatonnes of carbon in their biomass alone (FAO 2010). From the year 2005 to 2010, the carbon stocks have decreased by 0.5 gigatonnes yearly due to degradation, deforestation and poor forest management. (FAO 2010). This leads to an increase in the earth's average global temperature (Forster et al. 2007) which eventually leads to melting of glaciers and aggravating flood risk. Climate change boosts the spread of pest species in new areas affecting the interaction among species causing biodiversity and economic losses (De Meester et al. 2011). Human activity such as mining fossil fuels for the transportation industry may involve the systematic removal of forested areas that act as a natural barrier against hurricane winds. With the removal of such forest barriers, hurricane winds may exert more force on community infrastructure, and potentially cause more damage (Balmford et al. 2005).

Living things depend on ecosystem products and services in their everyday life and biodiversity loss will have a negative impact on living things if the ecosystem service is unable to meet social needs. Besides that, loss in biodiversity means loss in world food production as biodiversity plays a crucial role in ensuring the productivity of soil. Biodiversity is important in offering genetic resources for all livestock, plants and marine species harvested for food. Apart from that, rapid urbanization, logging and conversion for agriculture have not only caused forest to be at jeopardy around the world but have increased the rates of species extinction globally. For example, in the Philippines, 221 species of fauna and 526 species of flora have been included in the list of threatened species in the year 2008 (NEDA 2011). In addition, due to loss of biodiversity, the rate of species extinction is hundred times faster than in prehistory times (MEA 2005).

Empirically, there are very limited studies on the link between extinction of species such as plants, birds, mammals and fishes with natural disaster (Stern 2008; Schrag & Wiene, 1995; Khasnis & Nettleman 2005). The present study contributes further to literature of biodiversity loss due to natural disasters by employing two measures of natural disasters (number of occurrences and estimated damages as a percentage of GDP) on four threatened species (bird, fish, mammal and plants). This study will provide a comprehensive coverage on the impact of natural disasters on biodiversity loss on a wider perspective and in a more global context. This study hopes to contribute further novelty to the pool of existing literature on biodiversity loss by providing a more elaborate understanding on the extinction of species due to the impact of natural disasters.

LITERATURE REVIEW

In the past decade, there have been extensive researches exploring the determinants of natural disasters. However, literature on the social and economic consequences of natural disasters on biodiversity loss is still limited as it is only recently that this data has become more available. Numerous studies differ in their data, methodology and findings. Biodiversity loss is interpreted as "the long-term or permanent qualitative or quantitative reduction in components of biodiversity and their potential to provide goods and services, to be measured at global, regional and national levels" (Balmford et al. 2005). Therefore, the loss of biodiversity can be either when "diversity per se is decreased due to species extinction or if the potential of the components of diversity to provide a particular service is diminished such as through unsustainable harvest" (MEA 2005).

Studies by Pimm and Raven (2000) and Thomas et al. (2004) found that climate change causes biodiversity loss in the future and changes in global ecosystem services. Past studies have explored different biodiversity indicators in modeling the effect of biodiversity loss in the value of ecosystem services. Costanza et al. (2007) found that there exist a direct relationship between net primary production (NPP) and species richness in the United States while similar finding by Ojea et al. (2012) when they studied the regional forest ecosystem at a global scale by using meta-analysis. Biodiversity loss generally causes the decline rates of the species loss as to meet the demands of the growing populations, habitat conversion and changes in the environmental conditions.

Literature has approached biodiversity loss in various ways. Firstly, the proxy used for biodiversity loss in many literatures is deforestation, which explain the relationship between changes in biodiversity loss and forest area (Dietz & Adger 2003). The second one is using the National Biodiversity Risk Assessment Index (NABRAI) developed by Reyers et al (1998) which takes into consideration indices of pressure, state and response. Thirdly, measuring the threat contained in the IUCN's red list (Naidoo & Adamowicz 2001). Natural disasters cause changes in species interactions (Roznik et al. 2015) and delays recovery process with any disturbance from human activities or alien species. (Hayasaka et al. 2012; Hughes & Denslow 2005). The findings of Hayasaka et al. (2102) concluded that vegetation that were destroyed by tsunami, returned to normal within 7 years as there were no human activities reported in that area. In contrary, the vegetation of resort beaches were unable to resume their original composition as compared to alien species.

Loss in biodiversity causes the ecosystem to be less resilient, more exposed to shocks and disturbances making it less able to supply humans with needed services, hence affecting human capital (Roznik et al. 2015). Much of the current literature on biodiversity pays particular attention to human development, as it is one of the greatest threat to species extinction (Spicer 2004; McLellan et al. 2014; McKee et al. 2004; Halkos 2011; Stern 2008). Hansen (2013) found that the species extinction due to rapid growth of human population, urbanization, logging and conversion for agriculture, cause a net loss of 11.5 million hectares of the forest a year since 2000.

Loss of forest increased the global carbon dioxide (CO_2) emission and created a negative effect on the climate change, water supplies and biodiversity richness (Hsu et al. 2014; Crawford et al. 2006; Müller et al. 2013; Struebig et al. 2015). Forest, being the most diverse and widespread ecosystems on earth, is vital to millions of people and according to WWF, almost 46000 to 58000 square miles of forest are lost every year which affect the livelihood of people and threatens a wide range of animals and plants (WWF 2014). Through photosynthesis, forest removes carbon from the atmosphere and deforestation causes carbon back to the atmosphere and these gas emissions contribute to changes in pattern of weather and water, rising temperatures and increase the frequency of extreme weather events. Stern (2008) found that an increase of over 2°C induced by a greenhouse emission will be twice as much in 2035 and due to melting of glaciers will increase flood risk and reduce water supplies to one sixth of the world's population. Studies by Schrag and Wiener (1995) and Khasnis and Nettleman (2005) concluded that due to global warming, the Arctic will be ice-free in the year 2100 and majority of the species may become extinct.

In addition, removal of mangrove forest and coral reefs, created ecosystem degradation and contributed to a loss of natural barrier against tsunamis and cyclones (Giri et al. 2015; Balmford et al. 2005). In the same vein, several studies have linked biodiversity loss due to obtaining petroleum in the deep waters (Fisher et al. 2014) and natural gas using hydraulic fracturing (Ellsworth 2013). Together, these studies indicate that human activities disturb the ecosystem and when disaster strikes, there will be more damage to human lives, livelihoods and environment (UNEP 2009; Cochard 2011) and increased economic losses (Cochard 2011).

In contrary, natural disaster events have resulted in the evolution of new species and traits. Volcanic activity have created islands (Ingimundardóttir et al. 2014; Abe 2006) with endemic species (Green et al. 2012; López et al. 2010) which attract tourism in the long-term. The ashes from volcanic activities provide nutrients while pumices "act as dispersal agents for the long-distance movements of marine invertebrates, macroalgae, and bacteria" (Bryan et al. 2012). Earthquake, on the other hand, creates ponds and lakes. A study by Lescak et al. (2015) reported the existence of a pond of freshwater habitat in Alaska that was created by the island uplift due to the Great Alaska Earthquake in 1964.

Having reviewed past literature on biodiversity loss, we find that very few studies investigated the impact of natural disasters on biodiversity loss utilizing the quantile regression approach (Bhuiyan 2018). Most of the past literature reviews rely on ordinary least square method. The majority of the literatures contributed to biodiversity loss research focus on specific species in threat or a certain type of disaster. Therefore, the current study seek to contribute further by examining the impact of total natural disasters on four endangered species using more explanatory variables.

METHODOLOGY

This study utilized a model specification following the work of Halkos (2011). Following his model specification, we augmented the threatened birds, fish, mammal and plants species as a function of total natural disaster (TND), carbon dioxide emission (CO_2), income (GDPPC), income squared ($GDPPC^2$), urban population (Urbanpop) and percentage of protected area (protect) as follows:

$$Bioloss = f(TND,\ CO_2,\ income,\ income\ squared,\ Urbanpop,\ protect) \quad (1)$$

When equation (1) is specified in a stochastic form, the following equation is obtained;

$$LNBioloss_{ij} = \beta_0 + \beta_1 LNND_I + \beta_2 LNCO_{2i} + \beta_3 LNGDPPC_i + \beta_4 LNGDPPC_i^2 + \beta_5 LNUrbanpop_i + \beta_6 LNprotect_i + \varepsilon_i \quad (2)$$

where β_1, β_2, β_3, β_4, β_5, β_6 and ε are parameters to be estimated with ε being the error term and i = 1, 2, 3……110 number of countries. It is expected that all the parameter have a positive sign except for income. The variables used in the present study are:

1. Variable $LNBioloss_i$ denotes biodiversity loss. Biodiversity loss in this study is measured by using the number of threatened species; birds ($LNBirds_i$), fish ($LNFish_i$), mammal ($LNMammal_i$) and plant ($LNPlant_i$).
2. $LNTND_i$ represent the number of occurrences of total natural disasters
3. $LNCO_{2i}$ represents the carbon dioxide emission
4. $LNGDPPC_i$ represents the level of economic development and is measured by gross domestic product per capita whereas $LNGDPPC^2{}_i$ is income per capita squared
5. $LNUrbanpop_i$ is the urban population growth
6. $LNprotect_i$ represents the percentage of protected area

The main purpose of this study is to provide empirical evidence of the impact of total natural disasters on biodiversity loss. In the present study, we used the number of endangered species (fish, mammal, bird and plants) to measure biodiversity loss in the year 2015 for a sample of 110 countries (Appendix 1). The numbers of threatened species include species that are critically endangered, endangered or vulnerable but excludes species that are known to be extinct and whose status is not sufficiently known (IUCN 2014).

The natural disaster data was obtained from Emergency Events Database (EM-DAT) maintained by the Center for Research on the Epidemiology of Disasters (CRED). EM-DAT defines a disaster as a natural situation or event, which overwhelms local capacity and/ or necessitates a request for external assistance. For a disaster to be entered into the EM-DAT database, at least one of the following criteria must be met: (1) 10 or more people are reported killed; (2) 100 people are reported affected; (3) a state of emergency is declared; or (4) a call for international assistance is issued. The main independent variable of interest for this model is the number of occurrences of total natural disasters.

Apart from natural disaster, we also include per capita Gross Domestic Product, Gross Domestic Product per capita squared, urban population growth, per capita CO_2 emissions and the percentage protected land area as control variables. All the control variables are for the year 2015 except for per capita CO_2 emissions and the percentage protected land area, which is in the year 2014.

GDP per capita is used as a proxy to measure income per person. Countries with higher income per capita are expected to have lower biodiversity loss as they are to replace towards agricultural and industrial technologies that are less harmful to the environment and subsequently attracting tourism (Halkos 2011). Urbanization is one of the greatest threat to species extinction (Spicer 2004; McLellan et al. 2014; McKee et al. 2004; Halkos 2011; Stern 2008). Increasing population growth in urban areas increases the demand for natural resources and expansion to urban areas leading to destruction of forest, habitat and natural resources. Loss of forest increased the global carbon dioxide (CO_2) emission and created a negative effect on the climate change, water supplies and biodiversity richness (Hsu et al. 2014; Crawford et al. 2006; Muller et al. 2013; Struebig et al. 2015). Protected area is an effective mean to address biodiversity loss as these areas store and sequester carbon in soils and vegetation (MacKinnon et al. 2011; Dudley et al. 2010) and aims to maintain natural habitats and natural resources (World Bank 2014).

The value of gross domestic product per capita squared has a significantly negative impact on biodiversity loss and is necessary to determine the non-linearity between GDP per capita and biodiversity loss. The GDP per capita and biodiversity loss share an "inverted U" relationship similar to Kuznet's curve (Kuznet 1955) which shows that as GDP per capita increases from low level to a higher level, biodiversity loss first increases to a turning point and decreases after that point. This can been seen in the scatter plot of GDP per capita and biodiversity loss in terms of log in Figure 2. All the data were obtained from World Development Indicators (WDI).

All the variables in this study are transformed into natural logarithm and denoted by *LN*. Equation (2) is estimated using Ordinary Least Squares (OLS), a technique that summarizes the average relationship between a set of regressors and the outcome variable based on the conditional mean function. The present study then employs the quantile regression in describing the relationship of the independent variables at different points in the conditional distribution of the dependent variable (Koenker & Basset 1978). This provides a more complete description of the underlying conditional probability as there will be a number of different quantile regressions. The quantile regression is defined as follows:

$$LNBioloss_i = x_i'\beta_\theta + \varepsilon_{\theta i} \quad (3)$$

$$Quantile\ (LNBioloss_i|x_i) = x_i'\beta_\theta \quad (4)$$

where β_θ is the vector of the unknown parameters associated with the θ^{th} quantile, x_i' is the vector of explanatory variables as defined above and "$\varepsilon_{\theta i}$" _"θ_i" is the unknown error term. The $Quantile_\theta\ (LNBioloss_i \mid x_i)$ denotes the conditional quantile of $LNBioloss_i$ for the θ-th quantile given x with $0 < \theta < 1$.

Quantile regression (QR) developed by Koenker and Basesett (1978) is used to examine the effect of natural disasters on biodiversity loss. QR is an extension of least square method and it allows us to obtain information about the impact of covariates at different quantiles of the dependent variable. The least square model is set as follows:

$$y_i = x_i'\beta + \mu_i \quad (5)$$

where y_i is dependent variable; x represents the vector of independent variables; β is the set of coefficients. The following function (equation 6) can be solved to obtain the estimation of conditional expectation function $E(Y/x)$:

$$\min_{\beta = \mathcal{R}} \Sigma_{i=1}^{n}(y_i - x_i'\beta)^2 \quad (6)$$

Likewise, the τ^{th} sample quantile can be found by solving the equation below (Koenker and Basesett, 1978):

$$\min_{\beta = \mathcal{R}} \Sigma_{i=1}^{n}\rho_\tau(y_i - \alpha) \quad (7)$$

$Q_y(\tau/x)$ is the τ^{th} linear conditional quantile function and $Q_y(\tau/x) = x'\beta(\tau)$. The estimation of $\beta(\tau)$ can be found by solving the following equation:

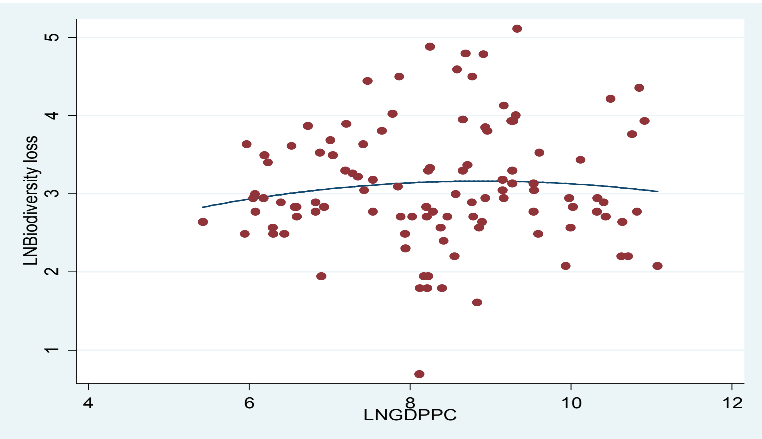

FIGURE 2. Scatter plot between Log GDP per capita and Log Biodiversity Loss

Source: WDI

$$\min_{\beta=\mathcal{R}} \Sigma_{i=1}^{n} \rho_\tau(y_i - x_i'\beta) \quad (8)$$

where ρ_τ is the weighting factor known as the check function where $\rho_\tau(z) = z(\tau - I(z < 0))$ and y_i, the conditional distribution of explained variable, has different values at different quantile given the value covariates x (Koenker & Hallock 2001). At any point where $0 < \tau < 1$, check function is describe as:

$$p_\tau(\theta_i) = \begin{cases} \tau\theta_i & if\ \theta_i \geq 0 \\ (\tau - 1)\theta_i & if\ \theta_i < 0 \end{cases} \quad (9)$$

where $\theta_i = y_i - x_i'\beta$.

The equations (8) and (9) above denote the quantile minimization function shown below:

$$\hat{\beta}_\tau \min_{\beta=\mathcal{R}}[\Sigma_{iz\{y_i \gg x_i'\beta\}} \tau|y_i - x_i'\beta| + \Sigma_{iz\{y_i \gg x_i'\beta\}}(1-\tau)|yi - xi'\beta|] \quad (10)$$

The quantile regression coefficients as expressed in equation (10) can be computed by minimizing the sum of absolute error in the model. The regression allows the estimation of the relationship between the covariates and dependent variable at different percentile based on the user specification. For example, the estimation is a median regression if $\tau = 0.5$ (50% quantile).

EMPERICAL RESULTS

The bootstrap method used in quantile regression generates heteroscedasticity robust estimates and allows joint distribution of several quantiles regression estimators by which the Wald slope equality test can be performed (Koenker & Hallock 2001). In this study, ten thousand bootstrapping repetitions is performed for each case. The Wald slope equality test determines whether it is necessary to employ the approach of quantile regression to examine the effect of natural disasters on biodiversity loss for the 110 countries. The null hypothesis for the Wald test is that coefficients of the inter quantile slope are equal and if we fail to reject the null hypothesis, it indicates that the quantile regression should not be used for this analysis.

However, before proceeding with the quantile regression analysis, the descriptive statistics of the dependent variables are first examined. Table 1 below shows that the mean and median between the four dependent variables (threatened birds, fish, mammals and plants) differ substantially. Large variation are also detected in the standard deviation, skewness and kurtosis between these variables. The distributions for all the four dependent variables are right skewed implying that the datasets deviates from the normal distribution. Plants exhibits the most positive skewness followed by mammal, birds and fish. The value of kurtosis for all the four dependent variables are positive and exceeds three, which implies that the distributions are asymmetric. It indicates leptokurtosis, which means that the distributions have higher peak and fatter tails than the normal distribution. The largest excess kurtosis is 57.697 (plant) and the lowest is 10.034 (fish). The p-value for Jacque-Beta test is less than 1% for all the four dependent variables, which indicates the non-normality of the biodiversity loss variable. Therefore, it is justified to use quantile regression in the present study.

TABLE 1. Descriptive statistics of the number of the threatened species

	Birds	Fish	Mammal	Plant
Mean	19.702	35.159	15.327	69.615
Median	13.5	27.5	9	12.5
Minimum	0	0	0	0
Maximum	165	247	185	1848
Standard Deviation	23.328	36.117	21.678	171.247
Skewness	3.178	2.684	3.890	6.424
Kurtosis	12.594	10.034	21.625	57.697
Jarque-Bera test	0.000	0.000	0.000	0.000

The number of occurrences of total disasters is used to examine the impact of the disasters on biodiversity loss. Quantile regressions is estimated at seven different quantiles: 5%, 10%, 25%, 50%, 75%, 90% and 95% and for comparison purposes, the empirical results from the OLS are reported. The quantile regression results for the effect of occurrences of natural disasters on biodiversity loss is presented in Tables 2 to 5 and in Figures 3 to 6. The estimated standard errors are reported in the parentheses.

Figures 3 to 6 presents the graphs of quantile regression, which shows the effects, and the magnitude of the effects of the explanatory variables over different quantiles. The horizontal and vertical axes display the different quantiles and the quantile coefficient, respectively. The horizontal dashed lines seen in the diagrams are the OLS coefficients with their 95% confidence interval. The zero-sloped conditional estimate line indicates countries place the same value on the explanatory variable across all the biodiversity loss level. The solid line represents the conditional quantile effect of the explanatory variables and the shaded area around the solid line represents the 95% bootstrapped confidence interval. The coefficients of OLS measure the change in the conditional mean whereas the coefficients of quantile regression measure the change in conditional biodiversity loss quantile resulting from a one-unit change in the explanatory variables, holding all other covariates fixed.

The lower and upper quantiles for most of the variables (shown in Figures 3 to 6) are well beyond the least square estimate confidence intervals, which suggest that quantile regression is necessary to describe the relationship of occurrences of total disasters and species in danger. For example, in the case of threatened birds (Figure 3), the lower and upper quantiles for all the variables, except for urban population growth, are

TABLE 2. Regression results with threatened Birds as dependent variable

VARIABLES	OLS	5th quantile	10th quantile	25th quantile	50th quantile	75th quantile	90th quantile	95th quantile
LNOCC	0.722***	0.740***	0.724***	0.616***	0.611***	0.799***	0.664***	0.478***
	(0.0943)	(0.216)	(0.248)	(0.124)	(0.105)	(0.141)	(0.174)	(0.0798)
LNCO2	0.294**	0.629*	0.503	0.307	0.324**	0.392	0.123	-0.129
	(0.134)	(0.360)	(0.365)	(0.196)	(0.156)	(0.252)	(0.308)	(0.0981)
LNprotect	0.240***	0.0693	0.0598	0.182	0.187**	0.261**	0.426**	0.443***
	(0.0785)	(0.270)	(0.341)	(0.136)	(0.0897)	(0.115)	(0.199)	(0.0522)
LNGDPPC	0.959**	-0.870	-0.688	0.199	1.066*	1.732**	2.044**	2.282***
	(0.483)	(2.026)	(1.911)	(0.801)	(0.538)	(0.710)	(0.971)	(0.316)
LNGDPPC2	-0.0613**	0.0337	0.0272	-0.0221	-0.0679**	-0.108**	-0.116**	-0.126***
	(0.0280)	(0.109)	(0.109)	(0.0455)	(0.0312)	(0.0417)	(0.0551)	(0.0162)
LNUrbanpop	0.491*	-0.0222	0.0628	0.215	0.725**	0.721**	0.413	0.189**
	(0.260)	(0.535)	(0.720)	(0.423)	(0.298)	(0.344)	(0.265)	(0.0791)
Constant	-3.176	5.358	4.460	0.655	-3.728	-6.580*	-7.574	-7.907***
	(2.259)	(8.009)	(8.012)	(3.633)	(2.530)	(3.344)	(4.616)	(1.515)
Number of Observations	108	108	108	108	108	108	108	108
R-squared	0.4465	0.3348	0.3180	0.2130	0.2649	0.3276	0.3536	0.4189
Wald slope equality test		5.77 (0.0000) 19 df						

Notes: The dependent variable is threatened birds. The asterisks ***, **, and * are 1%, 5%, and 10% of significance levels, respectively. The numbers in parentheses are heteroscedasticity-robust standard errors. Quantile regression results are based on 10,000 bootstrapping repetitions.

higher than the least square estimate confidence intervals. These findings are further validated by the Wald slope equality test results shown in Tables 2 to 5. The test reveals that at 5% level, the null hypothesis for equality of coefficients across the different quantiles is rejected for all the threatened species, implying that the inter quantile slope coefficients are statistically significant. Therefore, the application of quantile regression for the biodiversity loss model in the 110 countries is justified.

In the first part, we examine the results of the birds in danger. The OLS results in the second column in Table 2, show that all the explanatory variables have significantly positive values except for GDP per capita squared, which is significant and negative. In particular, a 1% increase in the number of natural disaster occurrences is expected to increase the loss of threatened birds by about 0.72%. The estimated results of the quantile regression shown in columns 3 to 9 indicate that occurrences of natural disasters has a statistically significant effect on conditional loss of threatened birds in all quantile levels. This suggest that the number of occurrences is positively associated at small and large number of threatened birds' species. An increase by 1% in the number of occurrences is expected to increase loss in threatened birds by 0.61% at the 50^{th} quantile, which suggest that the estimate of the conditional median is lower than the OLS conditional mean location shift estimate of 0.72%. The difference in these values is due to the skewed conditional biodiversity loss that inflate expected location shifts estimated by the OLS model.

Independent variables other than occurrences have positive signs except for GDP per capita square. For CO_2 emission, a 1% increase is not expected to change the loss of threatened birds at the upper quantiles (after the 50^{th} quantile) but increases the number of loss in threatened birds by about 0.63% and 0.32% at the lowest (5%) and the middle (50%) conditional distribution, respectively. However, the other explanatory variables are all significant at the middle and higher quantiles.

Figure 3 illustrates the regression quantiles for the biodiversity loss covariates. The graph of the constant term represents the estimated conditional quantile function of the threatened species when there is no influence of the independent variables. The coefficients of protected area, GDP per capita and urban population growth increase from the lower to the upper quantile whereas CO_2 emission and GDP per capita squared move in the opposite direction. There is an unstable behavior with the number of natural disasters that occurred as it increases and decreases when we move from the minimum to the maximum quantile. GDP per capita, GDP per capita squared, protected area and urban population influences the countries with middle and higher biodiversity loss. Protected area and income per capita exhibits an increasing trend from the 0.5 to 0.95 quantile suggesting that countries with higher

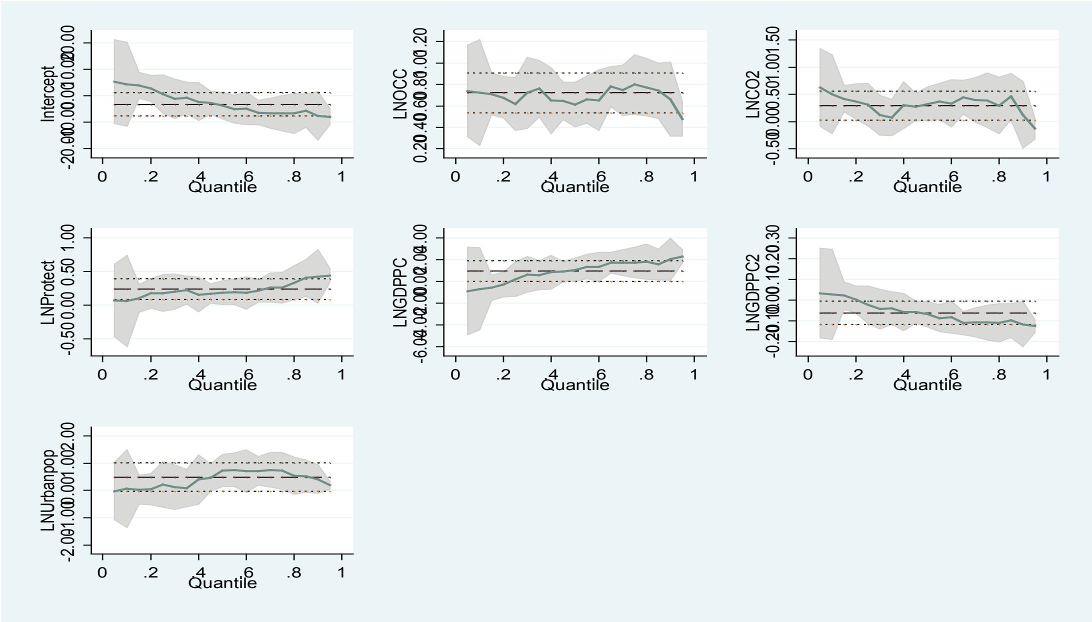

FIGURE 3. Quantile regression estimation plots: Occurrences of total disasters and threatened birds

biodiversity loss are more likely to be prone to more loss of threatened birds if the percentage of the protected area and income per capita becomes higher as compared to countries with lower biodiversity loss. The results of the urban population growth, on the other hand, implies that countries with lower biodiversity loss will experience more loss in birds in danger when the population grows.

The second part of this section indicates that for the OLS results of the endangered fish, only occurrences is significant, as shown in Table 3 and Figure 4. Occurrences of natural disaster is significant at all quantiles except for the 10th and 90th quantile. The conditional quantile

TABLE 3. Regression results with threatened fish threatened as dependent variable

VARIABLES	OLS	5th quantile	10th quantile	25th quantile	50th quantile	75th quantile	90th quantile	95th quantile
LNOCC	0.529***	0.910***	0.430	0.668***	0.494**	0.557***	0.414	0.428***
	(0.139)	(0.260)	(0.633)	(0.121)	(0.203)	(0.160)	(0.381)	(0.0590)
LNCO2	0.0824	0.451	-0.179	-0.194	0.0460	0.280	0.442*	-0.118**
	(0.198)	(0.465)	(0.725)	(0.198)	(0.297)	(0.195)	(0.243)	(0.0571)
LNprotect	0.115	0.216	0.00280	0.118	0.162	0.166	0.299	0.0756
	(0.116)	(0.329)	(0.500)	(0.128)	(0.174)	(0.120)	(0.321)	(0.0771)
LNGDPPC	0.478	-0.916	2.409	2.354***	0.902	-0.212	0.0952	0.977***
	(0.712)	(1.957)	(3.406)	(0.723)	(1.019)	(0.718)	(1.000)	(0.270)
LNGDPPC2	-0.0161	0.0709	-0.105	-0.108**	-0.0442	0.00744	-0.0110	-0.042***
	(0.0413)	(0.112)	(0.201)	(0.0417)	(0.0591)	(0.0401)	(0.0602)	(0.0150)
LNUrbanpop	0.513	0.882	0.670	0.374	0.435	0.528	0.770	1.147***
	(0.383)	(0.710)	(1.758)	(0.399)	(0.577)	(0.410)	(0.852)	(0.208)
Constant	-1.169	0.923	-11.35	-10.43***	-2.481	3.032	1.365	-2.897**
	(3.332)	(8.829)	(15.59)	(3.342)	(4.812)	(3.526)	(4.845)	(1.427)
Number of Observations	108	108	108	108	108	108	108	108
R-squared	0.2139	0.1519	0.2252	0.2031	0.1172	0.1601	0.2298	0.276
Wald slope equality test				6.88 (0.0000) 19 df				

Notes: The dependent variable is threatened fish. The asterisks ***, **, and * are 1%, 5%, and 10% of significance levels, respectively. The numbers in parentheses are heteroskedasticity-robust standard errors. Quantile regression results are based on 10,000 bootstrapping repetitions.

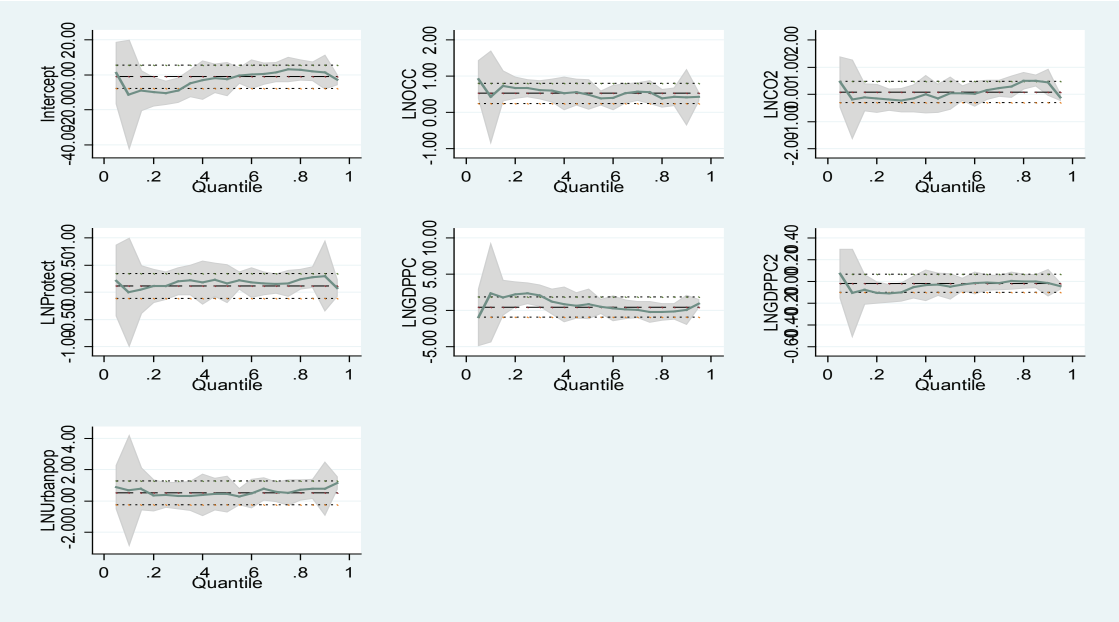

FIGURE 4. Quantile regression estimation plots: Occurrences of total disasters and threatened fish

estimates of CO_2 emission, income and urban population growth provide important inferences that is not shown in the OLS parameter estimates. Although OLS results suggest that these variables are not statistically significant in affecting the conditional loss in threatened fish, the quantile regressions indicate that these OLS inferences are not robust across the entire conditional biodiversity loss distribution. Marginal changes in CO_2 emission, income and urban population growth affect countries with higher loss of threatened fish. The protected area has a positive coefficient throughout the quantiles. However, all the coefficients are statistically insignificant at all

TABLE 4. Regression results with threatened mammal as dependent variable

VARIABLES	OLS	5th quantile	10th quantile	25th quantile	50th quantile	75th quantile	90th quantile	95th quantile
LNOCC	0.693***	0.770***	0.815***	0.645***	0.613***	0.827***	0.824***	0.815***
	(0.0972)	(0.0805)	(0.138)	(0.113)	(0.214)	(0.0962)	(0.190)	(0.145)
LNCO2	0.214	0.323***	0.052	0.234	0.192	0.254*	0.274	0.174*
	(0.138)	(0.0696)	(0.159)	(0.209)	(0.301)	(0.146)	(0.322)	(0.102)
LNprotect	0.270***	0.236***	0.256	0.225*	0.257	0.367***	0.197	0.210***
	(0.0809)	(0.0816)	(0.157)	(0.129)	(0.174)	(0.0858)	(0.185)	(0.0503)
LNGDPPC	1.230**	0.008	0.764	0.638	0.974	1.854***	2.762**	3.012**
	(0.497)	(0.298)	(1.015)	(0.753)	(1.079)	(0.513)	(1.161)	(1.258)
LNGDPPC2	-0.076***	-0.009	-0.044	-0.044	-0.062	-0.108***	-0.163**	-0.176***
	(0.0289)	(0.0153)	(0.0582)	(0.0433)	(0.0629)	(0.0286)	(0.0655)	(0.0661)
LNUrbanpop	0.958***	0.543**	0.857**	0.704*	0.875	1.403***	1.627***	1.582***
	(0.267)	(0.211)	(0.351)	(0.422)	(0.578)	(0.258)	(0.409)	(0.342)
Constant	-5.340**	-0.429	-4.254	-2.629	-3.950	-8.963***	-12.19**	-13.17**
	(2.329)	(1.578)	(4.328)	(3.519)	(5.028)	(2.468)	(5.646)	(6.409)
Number of Observations	108	108	108	108	108	108	108	108
R-squared	0.4159	0.2884	0.2558	0.2249	0.248	0.3114	0.3633	0.4088
Wald slope equality test				6.13 (0.0000) 19 df				

Notes: The dependent variable is threatened mammal. The asterisks ***, **, and * are 1%, 5%, and 10% of significance levels, respectively. The numbers in parentheses are heteroscedasticity-robust standard errors. Quantile regression results are based on 10,000 bootstrapping repetitions.

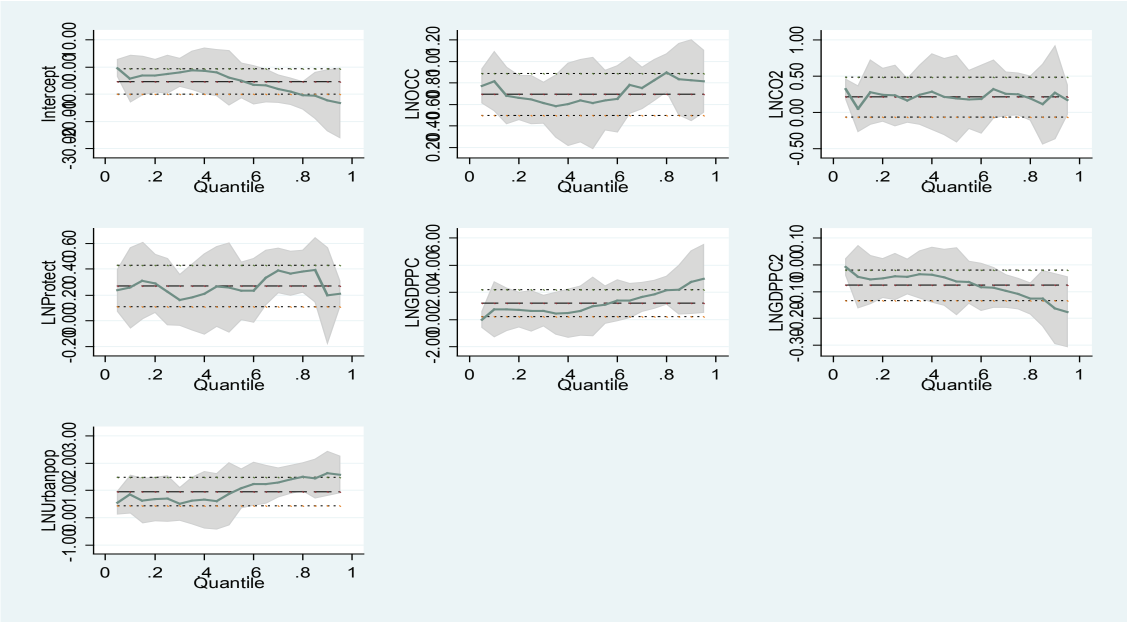

FIGURE 5. Quantile regression estimation plots: Occurrences of total disasters and threatened mammal

quantiles except for 95th quantile, implying that the control variables have no significance influence on the threatened fish species.

In the third part of this section, it is found that the number of disasters is statistically significant at all the conditional quantiles with non-linear consideration effects for countries above the 75th quantile as shown in Table 4. For countries with lower loss in threatened mammals, a 1% increase in the number of natural disaster occurrences causes the loss in threatened mammals to

TABLE 5. Regression results with threatened plant as dependent variable

VARIABLES	OLS	5th quantile	10th quantile	25th quantile	50th quantile	75th quantile	90th quantile	95th quantile
LNOCC	1.155***	1.359***	1.479***	1.582***	1.250***	1.196***	0.784**	0.596***
	(0.210)	(0.328)	(0.412)	(0.315)	(0.305)	(0.253)	(0.344)	(0.164)
LNCO2	-0.453	-1.030***	-1.309***	-1.321***	-0.406	-0.560	-0.513	-0.448
	(0.298)	(0.135)	(0.328)	(0.422)	(0.424)	(0.405)	(0.606)	(0.528)
LNprotect	0.688***	0.996***	1.031***	0.787***	0.702***	0.377	0.480*	0.853***
	(0.175)	(0.250)	(0.339)	(0.256)	(0.249)	(0.254)	(0.271)	(0.209)
LNGDPPC	3.093***	1.491	4.442***	3.225**	1.389	4.749***	3.793	4.808***
	(1.074)	(1.031)	(1.608)	(1.551)	(1.473)	(1.534)	(2.968)	(1.503)
LNGDPPC2	-0.168***	-0.0695	-0.223**	-0.151*	-0.0710	-0.264***	-0.201	-0.256***
	(0.0623)	(0.0592)	(0.0958)	(0.0908)	(0.0861)	(0.0866)	(0.169)	(0.0897)
LNUrbanpop	0.553	-0.968**	0.505	0.211	-0.0110	0.323	1.588	2.392***
	(0.578)	(0.465)	(0.905)	(0.898)	(0.847)	(0.820)	(1.450)	(0.879)
Constant	-13.81***	-7.501	-22.98***	-16.40**	-6.009	-18.51**	-16.24	-22.47***
	(5.028)	(4.696)	(6.541)	(6.872)	(6.911)	(7.506)	(14.66)	(7.617)
Number of Observations	108	108	108	108	108	108	108	108
R-squared	0.3302	0.2121	0.1962	0.2197	0.2055	0.1891	0.2355	0.2372
Wald slope equality test				10.29 (0.0000) 19 df				

Notes: The dependent variable is threatened plants. The asterisks ***, **, and * are 1%, 5%, and 10% of significance levels, respectively. The numbers in parentheses are heteroskedasticity-robust standard errors. Quantile regression results are based on 10,000 bootstrapping repetitions.

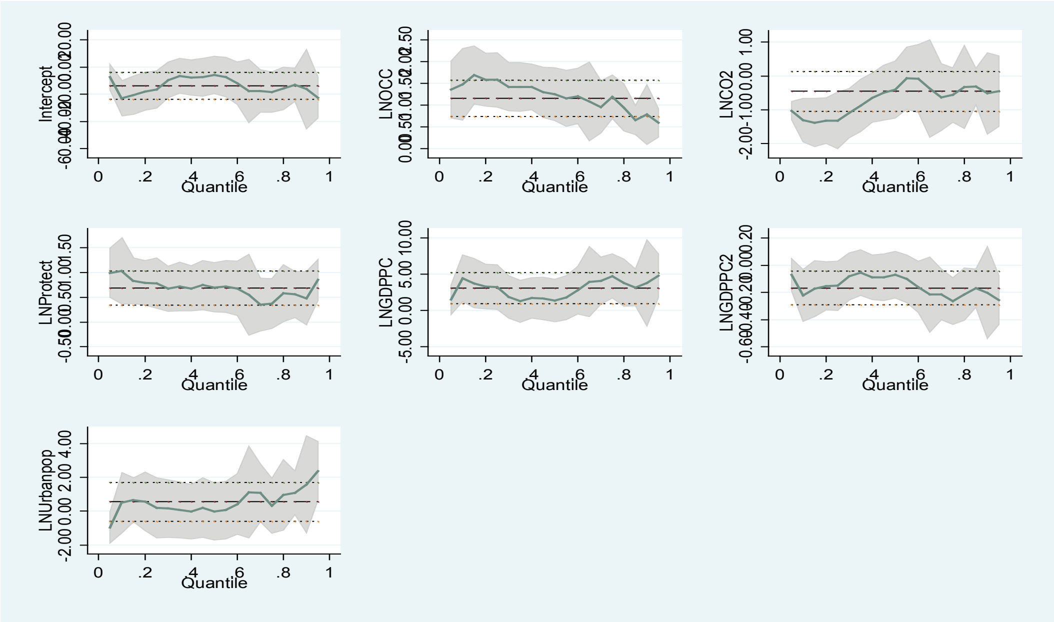

FIGURE 6. Quantile regression estimation plots: Occurrences of total disasters and threatened plants

increase between 0.61% to 0.77% but marginal increases of this trait are valued between 0.81% to 0.83% for countries with higher loss of mammals. The factor CO_2 emission is not significant for the OLS but is positively significant at the lowest (5%) and the upper (75% and 95%) conditional distribution. Protected area is significant for 0.5, 0.25, 0.75 and 0.95 quantile whereas income per capita is significant for the upper quantiles. Urban population growth is significant for all quantiles except for the 50^{th} quantile.

The coefficient of urban population growth becomes bigger at higher quantiles except for 50^{th} quantile as we move from the 5^{th} to the 95^{th} quantile as shown in Figure 5. This implies that urban population growth effect on threatened mammals is greater at higher quantiles. The coefficient of income per capita becomes larger at higher quantile whereas the GDP per capita squared becomes smaller at these quantiles suggesting that the income per capita is much greater in the countries with higher biodiversity loss but after a certain point, the income per capita decreases with higher biodiversity loss.

In the last part of this section, we examine the results of the plants in danger as shown in Table 5 and Figure 6. Occurrences of natural disasters is positive and statistically significant with biodiversity loss at all the quartile levels. It exhibits a decreasing trend from the 0.5 to 0.95 quantile suggesting that countries with lower biodiversity loss are more likely to be prone to more loss of threatened plants if the number of occurrences becomes higher as compared to countries with higher biodiversity loss. CO_2 emission is positively significant only at the lower conditional distribution, which implies that the CO_2 emission influences countries with lower number of threatened plants, but does not significantly affect the countries with higher number of threatened plants. Protected area for endangered plant is significant at all the quantile except for 75^{th} quantile whereas income per capita and squared income per capita are significant at 0.1, 0.25, 0.75 and 0.95 quantile. The effect of urban population growth is much greater for countries with extremely high loss or extremely low loss of threatened plants.

CONCLUSION

Quantile regression is used to explain the relationship between occurrences of total disasters and species in danger. The approach is justified as the lower and upper quantiles for most of the variables are well beyond the least square estimate confidence intervals. In addition, the inter quantile slope coefficients are significant in the Wald slope equality test. The findings of the present study show that occurrences of natural disasters have statistically significant effect on conditional loss of threatened birds, fish, mammals and plants in all quantile levels due to the destruction caused by different types of disasters. The impact of these disasters will destroy species, leading them to extinction, directly or through the loss of its habitat and food source (Rathore & Jasrai 2013). Some of the species that are destroyed cannot be recovered whereas certain species need to undergo recovery process due to the disturbances caused by the disasters (Roznik et al. 2015). They also found that the interaction of species changes due to the disturbances caused by the disasters and consequently affects the natural recovery processes. In addition, human activities during the recovery process, in the aftermath of disasters, contributes to further destruction to the ecosystem and extinction of species (Hayasaka et al. 2012). Furthermore, extinction of species especially the higher consumers can alter the food web and reduce plant biomass, the structure of vegetation and disease epidemic (Estes 2011; Shurin 2002; Duffy 2007).

The results of the present study suggest that countries with lower biodiversity loss are more likely to experience decrease of endangered plants with the increasing number of natural disaster occurrences as compared to countries with higher biodiversity loss. These countries will also experience more loss in birds in danger when the population grows. A study by Gill et al. (2009) found that increase in natural disasters events have made indigenous plants more vulnerable to the increasing number of diseases and pests. On the other hand, countries with higher biodiversity loss are more likely to face decrease in threatened birds due to the increase in the percentage of the protected area and income per capita as compared to countries with lower biodiversity loss.

Surprisingly, it was found that all the variables have no significance influence on the threatened fish species. On the other hand, urban population growth effect on threatened mammals is greater at higher quantiles whereas income per capita is much greater in the countries with higher biodiversity loss but after a certain point, the income per capita decreases with higher biodiversity loss. This is consistent with the study done by Hansen (2013). CO_2 emission influences countries with lower number of threatened plants, but does not significantly affect the countries with higher number of threatened plants, which is coherent with (Crawford et al. 2006; Struebig et al. 2015; Hsu et al. 2014; Muller et al. 2013). The increased level of CO_2 have modified forest composition through wild fires, increase in number of pest and invasive species, leading to extinction of certain tree species (FAO 2000). Protected area, income per capita and squared income per capita for endangered plant are significant at almost all the quantile whereas the effect of urban population growth is much greater for countries with extremely high loss or extremely low loss of threatened plants. The impact of natural disasters on loss of biodiversity will lead to economics losses especially in the tourism sector (Dudgeon et al. 2006).

Countries with lower biodiversity loss are more likely to experience decrease of endangered plants with the increasing number of natural disaster occurrences as compared to countries with higher biodiversity loss. These countries will also experience more loss in birds in danger when the population grows. However, countries with higher biodiversity loss are more likely to face decrease in threatened birds due to the increase in the percentage of the protected area and income per capita as compared to countries with lower biodiversity loss.

All the variables have no significance influence on the threatened fish species whereas urban population growth effect on threatened mammals is greater at higher quantiles. Income per capita is much greater in the countries with higher biodiversity loss but after a certain point, the income per capita decreases with higher biodiversity loss. CO_2 emission, on the other hand, influences countries with lower number of threatened plants, but does not significantly affect the countries with higher number of threatened plants. Protected area, income per capita and squared income per capita for endangered plant are significant at almost all the quantile whereas the effect of urban population growth is much greater for countries with extremely high loss or extremely low loss of threatened plants.

Bolder steps need to be taken in order to conserve and preserve the species, flora and fauna as these species continue to extinct due to natural disasters and environmental degradation. Efforts of reforestation such as the mangrove project will dampen the impact of disaster related losses caused by tsunamis and hurricanes and create job opportunities. With the rapid increase in population growth and the value of economic activity, the government need to increase protected areas and restoration projects to ensure the safety of the threatened species. Besides that, to reserve and conserve the aquatic life zones, policy makers have to enforce strict laws and impose high fines to individuals and companies that dump waste and industrial dumping into lakes, rivers and ponds. These steps will help the economy of the country by attracting tourism.

As the world continues to face problems like urbanization and natural disasters, biodiversity loss will keep increasing and policy makers and individuals should adopt practices and policies to integrate nature into their daily lives. This will lead to urban development with the integration of nature based solutions such as green roof, urban gardens, grasslands and temporary nature which will improve quality of life. Education and public awareness on the importance of protecting biological diversity should be implemented at all levels through campaigns and activities as the actions to halt biodiversity loss need to be taken both locally and nationally. Policy makers and the government should implement ecofriendly policies such as proper disposal and waste recycling to diminish greenhouse effect in order to decrease biodiversity loss.

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Appendix 1. List of Countries

Afghanistan	Dominica	Lao PDR	Saudi Arabia
Albania	Dominican Republic	Lebanon	Sierra Leone
Algeria	Ecuador	Malawi	Solomon Islands
Angola	Egypt	Malaysia	Somalia
Argentina	El Salvador	Mali	South Africa
Australia	Ethiopia	Mexico	South Sudan
Bahamas	Fiji	Micronesia	Spain
Bangladesh	France	Mozambique	Sri Lanka
Belgium	Gambia	Myanmar	Sudan
Belize	Georgia	Namibia	Syrian Arab Republic
Bolivia	Ghana	Nepal	Tajikistan
Bosnia and Herzegovina	Greece	New Zealand	Tanzania
Botswana	Guatemala	Nicaragua	Thailand
Brazil	Guinea	Niger	Timor-Leste
Bulgaria	Guyana	Nigeria	Togo
Burkina Faso	Haiti	Mariana Islands	Tonga
Burundi	India	Pakistan	Turkey
Cabo Verde	Indonesia	Panama	Tuvalu
Cameroon	Iran	Papua New Guinea	United Kingdom
Canada	Iraq	Paraguay	United States of America
Chile	Ireland	Peru	Uruguay
China	Israel	Philippines	Vanuatu
Colombia	Italy	Poland	Venezuela
Congo	Japan	Portugal	Viet Nam
Costa Rica	Kazakhstan	Romania	Yemen
Côte d'Ivoire	Kenya	Russian Federation	Zimbabwe
Croatia	Republic of Korea	Rwanda	
Cuba	Kyrgyzstan	Samoa	