The Fisheries Crisis and its People:

An econometric Sustainable Livelihoods application for low-income artisanal fishers in Sierra Leone

Nathan Brock
University of Wyoming

History of Economic Thought
Dr. David Finnoff
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Abstract

The global fisheries crisis is a topic of significant research across fields, including economics. It is evident that the current global fish stocks are declining, which has motivated environmental protection measures to be implemented. Low-income countries and their inhabitants are unevenly harmed by these environmental impacts, as artisanal fishing villages are dependent on fisheries for subsistence and livelihood. This case is particularly true in Sierra Leone, where poverty is evident, artisanal fishing communities exist, and dependence on fisheries is high (Kassam, et al. 2017; Teh, et al. 2016). Policy makers in these countries are faced with the challenge of mitigating environmental disasters while still ensuring that livelihoods of local people are protected. The present paper argues that an econometric model would provide useful, empirical evidence to these policy makers as to the specific factors of livelihood, responding to the question: which factors in the livelihoods of low-income artisanal fishers are most significant, and therefore should be considered in policy decisions? The econometric model in this paper follows the Sustainable Livelihoods Approach to environmental protection and poverty reduction (Krantz 2001). Livelihood, measured by the United Nations Development Programme Human Development Index, is explained by economic, social, and environmental variables in a sustainable livelihoods framework. Results and viability of this model are discussed, followed by a discussion of further research to sharpen these results. The model is then tested to show its practical application for policy-makers in maximizing poverty alleviation outcomes. Research concluded that insufficient data has caused present results to be relatively inconclusive for Sierra Leone today, but the model design and rationale can be useful given a substantially larger dataset.

I. Introduction

Background

The crisis facing global fisheries today is a prevalent issue in modern literature. A standard renewable resource bioeconomic model outlines the outcomes of overfishing; when the harvest rate is greater than the than the rate of recharge, fish stock declines (Finnoff 2016; Erickson n.d.). This result is more than theory, as it has been continually realized in resources from years past to today (Pauly, Watson, & Alder, 2005; Guardia, et al. 2018). Research by Guardia, et al. (2018) estimates real resource declines and conservation failures because of such commercial overfishing. Overfishing has also been shown to lead to significant environmental damage, including harm to ecosystems (Clarke, et al. 2018) and growth of competitive species (Roth, et al. 2017), both of which can cause significant declines in fish stocks and lasting ecological impact.

Poverty related to the fisheries crisis augments its effects far beyond the environment alone. Low-income countries have been shown to experience the impacts of environmental degradation more severely than other, wealthier countries (Millennium Ecosystem Assessment 2005; Pauly, Watson and Alder 2005). In the context of world fisheries, this translates to uneven impacts being distributed to artisanal fishing villages located along the coasts of fisheries, manifest as food insecurity and low income (Pauly, Watson and Alder 2005).

These types of villages are known to contribute very little to GDP for countries (Lenselink 2002), making it easy for policy makers to overlook them in natural resource decisions. However, artisanal fishers may respond differently to policy due to the complexities of added exogenous social factors (Coulthard, Johnson and McGregor 2011), and therefore must be considered in policy decisions. For example, weak human capital caused by illiteracy, poor health, and other factors (Krantz 2001) can lead individuals to view policy incentives differently. Moreover, these same individuals are at greater economic risk due to poor resilience to economic shocks (Krantz 2001), which can affect policy outcomes. Lastly, these low-income country settings may socially condone specific livelihood advantages for individuals across gender, age, and social status (Krantz 2001). To ensure that policy outcomes are optimal, artisanal fishers must be specifically considered in decisions.

With the complexities of social factors playing an influential role in poverty outcomes in fishing villages, a unique analysis is necessary to inform poverty reduction policy properly. This paper proposes the use of the Sustainable Livelihoods model as a means to provide better information to policy makers hoping to combat poverty in artisanal fisheries and achieve substantial results. This paper will define an econometric analysis model based on the Sustainable Livelihoods approach by incorporating ecological, economic, and socio-institutional factors that influence well-being of artisanal fishers.

The Sustainable Livelihoods Approach

The Sustainable Livelihoods approach was originally designed to inform policy in combatting poverty by enhancing economic development and resiliency of communities, while also managing resources sustainably to ensure lasting benefits (Krantz 2001). This model is advantageous for small-scale fisheries, as it accounts for both the bioeconomic factors of fisheries that influence poverty conditions, and simultaneously considers the additional social complexities of such situations, the latter being undervalued in existing research (MEA 2005).

This analysis will evaluate how policies affect the well-being and sustainability of communities through three facets of the Sustainable Livelihoods Approach: economic, social, and environmental. In turn, this holistic analysis will enhance understandings of community responses to policies (Coulthard, Johnson and McGregor 2011), and in the end will reveal the effectiveness of the policy at achieving goals.

Country of Focus: Sierra Leone

The present paper will focus on artisanal fishing communities in Sierra Leone. This country was chosen because it is a candidate country suffering from lack of sustainability form the three facets of the Sustainable Livelihoods Approach (social, economic, and environmental). Sierra Leone is a poor country that is also dependent on its fisheries resource for both subsistence (social) and livelihood (economic) purposes. Additionally, its rich fisheries resource suffers from environmental degradation.

Sierra Leone is a low-income country. Its United Nations Development Programme (UNDP) Human Development Index (HDI)[1] in 2016 was 0.42, which is a relatively low value compared to the world average of 0.71. The country is also characterized by a life expectancy of just 48 and a 60% of its citizens live below the national poverty line (UNDP n.d.).

Sierra Leone depends on its fisheries for subsistence. Teh, et al. (2016) calculated fish dependency of various low-income countries using fish consumption (g/capita/day) as a percentage of total animal protein consumption. For Sierra Leone, fish dependency was the highest of all countries in their study at 76%. Fish consumption habits in Sierra Leone indicate that fish consumed are primarily sourced from the coast and artisanal fishing makes up the primary source of livelihood for coastal fishing communities (Kassam, et al. 2017; Thorpe, et al. 2009).

The country is economically dependent on this resource as well. The Food and Agriculture Organization of the United Nations (FAO) supports the notion that livelihoods also depend on the fishery. The FAO Fishery Country Profile for Sierra Leone (2008) identifies 530 fishing landing sites that are categorized as artisanal. A substantial 30,000 fishers derive livelihood directly from these fisheries, employing 8000 fishing crafts (FAO 2008).

From the environmental facet, Sierra Leone suffers resource abuse. Fisheries are overexploited due to consistent harvest of juveniles, illegal fishing, and inefficient enforcement of fishing laws, when they exist at all (Sub-Regional Fisheries Commission 2016). Combined with the high volume of exploitation experienced in Sierra Leone's fisheries (Mawundu and Thorisson 2011), it becomes clear that its resource is environmentally mismanaged.

The above discussion establishes Sierra Leone as the ideal candidate for the purpose of this research. It is an impoverished country characterized by resource dependency from both social and economic perspectives. Additionally, its resource is environmentally mismanaged. The three facets of the Sustainable Livelihoods Approach to poverty alleviation clearly exist pertinent issues in Sierra Leone, thus this country is the ideal country of focus for the present research.

[1] The UNDP HDI is assumed to be a reasonable measure of human development and well-being in this paper. It is an index value derived from a variety of social and economic factors, thus representing the current development status of a country from a holistic view. The present paper argues that this perspective is ideal when dealing with the complex problem of poverty alleviation.

Research Question and Hypothesis

The present paper intends to determine which of the proposed factors most affect livelihood for artisanal fishers in Sierra Leone. This information will inform future policy regarding fisheries management to ensure that the livelihoods of Sierra Leoneans are preserved with any changes in fisheries management. This research will answer the following question: do the following social, economic, and environmental variables have relationship with the human development index, measuring livelihood?

Econometric regression analysis methods are used to respond to the stated research question. Linear econometric analysis creates a best-fit line for data that comes as close as possible to matching the true line that would be created from a complete population data set. Research will enhance the model to the point that predicted values for coefficients of each variable in the regression model will be accurate estimates of the true realities existing in the population. The coefficients predicted in the model (β) will represent the strength of each variable's relationship to livelihood. If a relationship exists between livelihood and any of these other variables, β > 0. Therefore:

$$H_0: \beta = 0$$

$$H_A: \beta \neq 0$$

II. Model and Methods

Standard Regression Model

In keeping with conventional econometric analysis, a traditional multilinear regression model will be utilized:

$$y_i = \beta_0 + \beta_1 x_{1i} + \beta_2 x_{2i} + \cdots + u_i$$

The regression model of the true population would include all variables (x) that affect one single variable (y), thus there would be no error (u=0). Therefore, the greater the efficiency of this model, the lower the error term. This error term is lowered by eliminating bias using a variety of statistical modelling tools to be described in the following.

Explained Variable

The explained variable, y_i , will represent livelihood. Krantz (2001), the pioneer of the Sustainable Livelihoods approach, defines as the "capabilities, assets, activities required for a means of living." The model in this paper will explain livelihoods by measuring variable effects on UNDP HDI. HDI is ideal for the Sustainable Livelihoods approach, as it measures development in through individual capabilities, not economic growth (UNDP 2016), which is consistent with the model of Krantz (2001). Data for HDI were compiled from the UNDP (2016).

Economic Control Variables

Coulthard, Johnson, & McGregor (2011) explain livelihood in three dimensions: economic, social, and environmental. These three dimensions inspire the explanatory variables (all x) in this model.
Of the economic elements, the first apparent variable to consider is the marine fish economy in Sierra Leone. Changes in demand for marine fish products would likely impose direct effects on livelihood of

fishers. This model will use metric tonnes of marine fish production from FAO FIGIS data (2018) to measure of the variable *marfishprod*.

Aquaculture production is an excellent measure of an inland livelihood tradeoff, as fishers can choose to earn a living through aquaculture rather than fishing if the market incentivizes it. In Sierra Leone, aquaculture is known to exist but is underdeveloped (FAO 2008). Nevertheless, this aquaculture is a livelihood tradeoff to marine fishing.[2] If inland aquaculture grows, fishers choose to allocate time to aquaculture for livelihood gains, which could offset some effects of overfishing. Aquaculture will be measured in metric tonnes of production for the variable *aqua* using data from the FAO Fisheries Global Information System (FIGIS) online database (FIGIS 2018).

Intuitively, current household income also affects livelihood status. Household income will be measured using World Bank data for national net income per capita (2017). Evaluating this data, it can be inferred that the data grows exponentially and increases in variability as it rises.[3] For this data to be utilized more effectively in the model, the natural log (ln) can be taken across all data for net income per capita. The log of the data will have a constant variance, making it easier for the best fit line to fit the data. The net income per capita data (with the natural log taken) is represented in the model as ln*_netincomepc*.

Employment status can also affect livelihood. The World Bank ratio of employment to population data (2017) will represent employment status in the variable *employpopr*. Use of the ratio intends to offset the potentially drastic fluctuations in population and employment, given the high fluctuations in population growth in Sierra Leone (World Bank, World Bank DataBank World Development Indicators: Sierra Leone 2017).[4]

Social Control Variables

It is well known that Sierra Leone is a place of particularly unstable political climate, as civil war and social unrest have been prevalent in recent years (UNDP n.d.). Civil war and can have devastating effects on livelihood of impoverished groups in developing countries. Index data compiled by the FAO, tagged "political stability and absence of violence and terrorism," will be used in the model to measure political stability in the variable *polstab* (FAO n.d.).

The number of workers per household can also have an effect on livelihood, as more "hands on deck" in an artisanal fisher's household can potentially increase productivity. To account for family members working in households, the model will consider the percentage of total contributing family workers data from World Bank (2017) in the variable *famworkers*.

Environmental Control Variable

This paper is aimed at mitigating adverse effects of overexploiting the fishery resource on impoverished communities. Additionally, the Krantz Sustainable Livelihoods model includes an environmental nexus (2001). Therefore, it is necessary to include an environmental variable to represent the fishery resource itself. Béné and Heck recognize that Africa in particular is currently experiencing stagnating returns in its

[2] A livelihood tradeoff is essentially an alternative source of income. In certain cases, it may be optimal for fishers to allocate labor time away from fishing and towards aquaculture (or a mix of both) to maximize income.
[3] See Figure 1A (Appendix A) for graph of data.
[4] See Figure 1B (Appendix A) for graph of data.

fisheries, and the resultant effects are likely to damage livelihoods, particularly lower-income groups (2005). This same research emphasizes fish exports as a key source of livelihood of African fishers, thus this paper will consider total fish production in Sierra Leone to measure the declines in fish stocks, thereby capturing the negative effects of overfishing in the model. This variable is different from the previous marine fisheries production because it is a broader, more generalized view of the fisheries resource as a whole, rather than the economic production supporting livelihoods. By considering a holistic view of the fisheries in Sierra Leone, total fisheries production provides a broader perspective of the environmental impacts of continued overfishing on the resource.[5] Data for total fisheries production (*totfishprod*) in metric tonnes was gathered from World Bank data for this variable (2017).

Other Control Variables

The ability of the Sierra Leonean government to protect its citizens' rights, or government viability, is another important element to consider in livelihood. Local people may suffer from the effects of poor governmental market protection, which would cause loss of rents to market failures, and lead to decreased livelihood. The index of economic freedom will be used to measure government viability because it accounts for rule of law and regulatory efficiency, both of which are plausible indicators of market safety and efficiency. Heritage Foundation data for this index (2018) will be included in the variable *EFI*.

Fresh water availability is crucially important for well-being, so it will be imperative to consider its effects on HDI. The FAO has compiled time-series data for "access to improved water sources" as a percentage of the population who currently have access (FAO n.d.). These data will be used to include fresh water availability (*accesswater*) in the model.

Dummy Variables

The event of civil war in Sierra Leone mentioned prior is a significant factor that may affect data. Specifically, pre-civil war data may be inherently different from post-civil war data due to changes in infrastructure, laws and enforcement, societal standards, and any other amount of uncertain factors that affect well-being. This model will incorporate a dummy variable for Post-Civil War data to account for these differences, separating the data collected before and after the Sierra Leone civil war.[6] The Sierra Leone civil war endured from 1991 through 2000 (Uppsala Conflict Data Program 2016), thus the dummy variable *PostCivil* will consider data collected after 2000 in a separate category.

Data compilation proved difficult for Sierra Leone, given that it is a very underdeveloped country. The sparseness of available data for this country posed a significant limitation on the present dataset: values for given years were missing throughout it. Due to the brevity of scope in this research, it became

[5] Total Fisheries Production was used as an environmental measure also, in part, because other ideas for measuring overfishing, such as tonnes of harvest above the steady state for example, could not be found in existing data.

[6] Statistical data can contain inherent differences depending on which subset of the population the data were taken from (before or after the civil war, in this context). Dummy variables can resolve these discrepancies. These variables are binary, outputting either 0 or 1. All data collected from subsets of the population falling under the 0 category can be separated from those in the 1 category via a shift in the regression line that is created when the dummy variable outputs a "1".

unfeasible to collect this raw data directly from Sierra Leone, and thus the "holes" in the data inevitably persist. An additional set of dummy variables were used to fill these holes. Specifically, a dummy variable for each "x" variable that contains blank or missing observations was created for the model. Each dummy variable will shift the regression line to consider these missing observations, thereby correcting the problem of missing observations.[7] The following variable data had at least one missing observation: *netincomepc* (dummy variable denoted *missingn*), *EFI* (*missinge*), *polstab* (*missingp*), and *accesswater* (*missinga*). The coefficient discussion of these variables will be ignored, as they are merely included in the model as a tool for correcting the dataset.

The Situation-Specific Model

Considering each of the variables discussed previously, the final regression model appears as such:

$$HDI_i = \beta_0 + \beta_1 marfishprod_i + \beta_2 aqua_i + \beta_3 \ln\_netincomepc_i + \beta_4 employpopr_i + \beta_5 famworkers_i + \beta_6 totfishprod_i + \beta_7 EFI_i + \beta_8 polstab_i + \beta_9 accesswater_i + \beta_{10} PostCivil_i + (\beta_{11} missingn_i + \beta_{12} missinge_i + \beta_{13} missingp_i + \beta_{14} missinga_i) + u_i$$

Abbreviations for complete variable names were used in the model to facilitate a more efficient data entry process in SAS.[8]

Heteroscedasticity-Robust Standard Errors

Research considered the use of heteroscedasticity-robust standard errors to enhance results. These "White's Standard Errors" are used to account for the fact that in large population datasets such as the ones drawn from for this research are rarely homoscedastic. HDI may be inherently different for all people from different sexes and ages, thus each observation recorded for a male or a child may always be different from those for females and the elderly. Standard errors for observations are reweighted based on these inherent differences, creating a more homoscedastic set of observations (Brock, Wichman and Riddle 2017).

However, due to the small useable sample size for this data set, the use of heteroscedasticity-robust errors would likely cause more harm than good for the results of the model, only augmenting biases. For this reason, these errors were subsequently removed from the model regression.

Programming Methods

The statistical program SAS version 9.4 was utilized to run a standard multilinear regression analysis for the Sustainable Livelihoods model. Results from the regression are taken from outputs in this program. Microsoft Excel 2016 was utilized to streamline the process of compiling and unifying data in a single spreadsheet. This spreadsheet data set was imported into SAS in ".xlsx" format from Excel.

[7] Though this approach is not scientifically sound in many instances, the scope of this research posed limitations that made this approach the last resort to preserving the integrity of the dataset. See *Conclusion* for specific discussion of limitations.

[8] See Appendix A

III. Results

Parameter Estimates

The regression model was run in the SAS program, and the output results are displayed in Table 1:

Parameter Estimates				
Variable	**Parameter Estimate**	**Standard Error**	**t Value**	**Pr > |t|**
Intercept	0.72147	0.39000	1.85	0.0913
marfishprod	0.00000237	0.00000130	1.82	0.0965
aqua	0.00034623	0.00023335	1.48	0.1660
ln_netincomepc	-0.00718	0.01105	-0.65	0.5290
employpopr	-0.00901	0.00705	-1.28	0.2273
famworkers	0.00049351	0.00087698	0.56	0.5849
totfishprod	-0.00000218	0.00000122	-1.79	0.1017
EFI	-0.00107	0.00087172	-1.23	0.2461
polstab	0.00224	0.01093	0.20	0.8415
accesswater	0.00510	0.00265	1.92	0.0809
PostCivil	0.02562	0.01646	1.56	0.1480

R-Square	0.9960

Table 1: SAS output for the present Sustainable Livelihoods model.

The parameter estimates (β) are the best indication of the strength of relationship between HDI and given variables in the model.

From results, it is clear that the estimates of the largest relative magnitude ($> |0.005|$) are *ln_netincomepc*, *employpopr, accesswater,* and *PostCivil.*

T-Values

The t-test in the SAS program performs a statistical test to either accept or reject the null that estimates are statistically significant, testing the reliability of parameter estimates in the model. For significance, t-values must be greater in magnitude than 1.708 for a 90% confidence test ($\alpha = 0.1$), as this research will employ.[9]

T-test results in this model indicate that the following variables are significant: *marfishprod*, *totfishprod* and *accesswater*. Other variables in the model output results that are not statistically significant, and thus the parameter interpretations of these variables will be ignored in the following discussion.

R-Square

The R-square is a measurement of how well the estimate model in this paper fits with the true population model derived from data. The R-square for this model is 0.9960, or 99.6% accurate. Typically, the R-square indicates the model's accuracy in predicting true population estimates from the estimated best-fit line created by the regression. In this specific model's case, however, an astronomically high R-square value is indicative of endogeneity.[10]

In research, the model was reconfigured in a multitude of ways in an attempt to minimize potential endogeneity. The regression was run separately with the omission of each individual control variable to test for high correlations with HDI, but the R-square did not decline below 0.99 in any case. It is likely that endogeneity exists among multiple control variables in the model, which is incredibly difficult to test and control without a larger sample size. After efforts were exhausted, it was concluded that the small sample size used in this model made it difficult, if not impossible, to remove endogeneity completely. [11]

IV. Discussion

Marine Fish Production

The model recognized as strong relationship between marine fish production (*marfishprod*) and HDI. Based on research, this result complies with assumptions. This paper has discussed the influence of the marine fisheries sector on the economy of Sierra Leone; therefore, it is reasonable that this model would recognize a relationship between marine fish production and the livelihoods of Sierra Leonean fishers.

The t-value for *marfishprod* is statistically significant with 90% confidence, thus the parameter estimate can be interpreted. This result implies that for every 1 tonne increase in marine fish production, HDI is rises by a miniscule $2.3 * 10^{-6}$ index points. This result is quite interesting, as it would be assumed that marine fish production growth would significantly enhance livelihood for Sierra Leone, a country highly dependent on fisheries. Research indicates that the industrial Sierra Fishing Company is the primary fishing power in Sierra Leonean waters (Ssentongo and Ansa-Emmim 1986). It is possible that increased

[9] This confidence level is lower than the standard 95% confidence (or $\alpha = 0.05$) employed in scientific research. However, the small sample size and scope of this project posed limitations that forced this research to employ lower confidence. See *Conclusion* for specific discussion of limitations.

[10] Endogeneity occurs in models where control variables are correlated with each other. In other cases of endogeneity, specific control variables may be so highly correlated with the explained variable that they act as nearly exact replicas of the explained variable data. Both of these cases augments biases in the model.

[11] See *Conclusion* for specific discussion of limitations.

marine fish production does not benefit local Sierra Leonean artisanal fishers nearly as much as it benefits capitalists and shareholders of this larger, industrial operation.

Interestingly, the Franco-Soviet Company holds 20% of shares in the Sierra Fishing Company (Ssentongo and Ansa-Emmim 1986). Moreover, it is notable that a large number of foreign vessels are approved to access Sierra Leone's marine fisheries (Ssentongo and Ansa-Emmim 1986). Evidently, foreign fishing operations have a significant presence in the waters of Sierra Leone, this may also imply that the benefits of marine fish production do more to harm artisanal fishers of Sierra Leone, as exploitation revenues and fish themselves are depleted and shipped away from the country.

Total Fisheries Production

Total fisheries production as also recognized in the model to have affect HDI. As discussed prior, this variable was used to measure the effects of overfishing on Sierra Leonean artisanal fishers. Literature supports the notion that overfishing has had relatively higher effects on impoverished countries, and thus this result makes intuitive sense.

The t-test for *totfishprod* also determines the parameter estimate to be significant with 90% confidence; therefore, the parameter estimate can be interpreted. For a one metric tonne increase in fisheries production, HDI decreases by $1.22 * 10^{-6}$ index points. Though this is also a small result, the interesting point of discussion in the fact that *totfishprod* produced a negative relationship with HDI. It was inferred that overfishing would reduce total fisheries production and lead to a decline in HDI. However, the opposite result is shown. This relationship may be connected to the fact that increases in total fisheries production actually connects to an *increase* in overfishing. In other words, the data collected may simply be reflecting the amount of effort Sierra Leoneans have employed in marine fishing. If this is the case, then even with a slight increase in fisheries production, providing economic benefits for Sierra Leoneans, the overall HDI of Sierra Leone would decline due to the stronger effects of overfishing on this highly resource-dependent country.

Access to Improved Water Sources

Access to improved water sources (*accesswater*) is related to HDI as well, fitting with initial assumptions. Fresh water is crucially important to life, health, and efficacy in any human society in existence. By this notion, it is reasonable that increased fresh water availability would increase HDI, and in turn enhance livelihood.

Accesswater passed the t-test, and therefore its parameter estimate is significant. It can be concluded that with every 1% of the population able to access improved water sources, a 0.0051 increase in HDI will result. This parameter implies that fresh water availability is a factor of paramount importance for policy makers hoping to enhance livelihood in Sierra Leone. Though the model has revealed an obvious result, this research outcome is valuable to advancing confidence in freshwater development as a means of improving the Sustainable Livelihood of Sierra Leoneans.

Post-Civil War (Dummy Variable)

Dummy variables require a unique interpretation. Since they are designed to shift the regression model based on subsets of the population, the parameter estimates on these variables can be interpreted to measure the average difference between these two subsets of data.

According to results, *PostCivil* failed the t-test, and thus its parameter estimate cannot be used to draw conclusions about the average differences in Sierra Leone before and after its civil war. However, this variable revealed a surprisingly high parameter estimate that is still interesting to discuss. Given a more robust dataset, it is possible that there truly is a difference in Sierra Leone as a result of the war. On the other hand, it is also plausible that a country with such a low HDI before the war would not realize a drop in HDI as significant as a country with a higher starting HDI. Either case is a possibility in reality, but no reliable conclusions can be drawn from this study.

V. Application and Policy Recommendation

The purpose of the present model is to determine the specific variables for policy makers to target in real world, applicable policy to improve livelihood for Sierra Leoneans. For example, such an application could be driven by the variable Marine Fisheries Production, with a parameter estimate of $2.3 * 10^{-6}$. As discussed, this parameter implies that a one metric tonne increase in marine fisheries production causes an HDI increase of $2.3 * 10^{-6}$. Or, an increase in marine fisheries production of approximately 126,086.96 metric tonnes would increase HDI by 0.29, bringing the HDI of Sierra Leone up from 0.42 to meet the current world average HDI of 0.71 (UNDP n.d.). In this way, the model can be used to determine the precise amount of necessary change required to improve HDI; in turn, policy can set goals to meet this change amount.

As was previously discussed, a large number foreign catches from industrial vessels under the Sierra Fishing Company capture benefits of Sierra Leone's fisheries, without benefits reaching artisanal fishers and impoverished Sierra Leoneans. Additionally, illegal catches from these foreign sources have been a growing concern in Sierra Leonean waters (Seto, et al. 2017; Sub-Regional Fisheries Commission 2016). Between 1950 and 2015, foreign legal and illegal catches were estimated by Seto, et al. to be 5.4 million tonnes (2017), an average of about 83,000 metric tonnes per year.

In this example, policy could aim to increase marine fisheries production by about 126,000 metric tonnes. Policy can aim at enforcing property rights, reducing the amount of illegal catches to zero. Additionally, prioritizing domestic producers by strictly enforcing fishing boundaries could theoretically bring foreign catches to zero as well. This policy change would increase domestic marine fisheries production by 83,000. For the remaining 43,000, evidence supports that enforcement of shore fishing zones and improved technologies[12] have increased reported catches from local fishers by about 56,000 metric tonnes in just 5 years, an average increase of 11,200 metric tonnes per year. This means that, with the implementation of policy that protects domestic fishers in Sierra Leone, assuming perfect enforcement, illegal and legal foreign catches can be reduced to the point that Sierra Leoneans can realize improved HDI that meets the worldwide average in just about 4 years. Realistically, in a world where property rights are not strictly enforced, this improvement can still practically occur within a reasonable time frame; even doubling this time frame to 8 years would result in an incredible poverty alleviation outcome.[13] Using the present model in this way, policy-makers are empowered; they can create effective policies that target the specific

[12] Seto, et al. recognize both of these improvements as a part of a post-civil war recovery period (2017).

[13] See Albers, et al. and other current research regarding enforcement parameters. The future of research holds answers regarding the specific effects of low-income country budget and enforcement tradeoffs to inform the exact feasible time frame for this theoretical poverty alleviation policy to complete its goal.

elements of society that will maximize poverty alleviation outcomes without a substantial trial-and-error policy process.

VI. Conclusion

Summary

The present paper introduces research that is intended to inform more effective poverty alleviation of Sierra Leonean artisanal fishers. Given the current state of overfishing and rapidly declining fish stocks around the globe, fishery-dependent countries such as Sierra Leone are at risk of being significantly impacted. Through the Sustainable Livelihoods approach for combating poverty, an econometric model was created to determine the effects of policy change on society beyond GDP per capita.

In Sierra Leone, marine fisheries production, total fisheries production, and access to clean water sources emerged as statistically significant elements of society that affect livelihood. Policy makers are advised to consider these variables foremost in all policy decisions. Using this model, policy can be tested to consider how changes in certain variables on society will affect livelihood.

Future policy in aimed at alleviating poverty in Sierra Leone should consider the importance of these variables based on the Sustainable Livelihoods approach. Specifically, targeting the Sierra Fishing Company and enforcing property rights is a practical policy application of this model; improved property rights enforcement that prioritizes domestic marine fisheries production could improve HDI from its current level of 0.42 in Sierra Leone to meet the world average of 0.71 within a surprisingly reasonable time frame. This application augments the power of this model for policy-making. Given accurate and robust data, an econometric Sustainable Livelihoods model can be used to directly alleviate poverty with preciseness.

Limitations and Further Research

This model is a powerful tool with detailed scientific research to back it. However, it was made clear in prior discussion that there are a number of factors that pose limitations on the viability and usefulness of this model. Here, these limitations will be discussed, and reasoning behind research decisions will be addressed.

The first important limitation in the present model is the absence of observations. As described in *Methods*, dummy variables were used to correct for these gaps in data. Again, this method is not ideal in most scientific cases, but the lack of sufficient data available for this particular analysis proved to be a significant research hurdle. As a result, this last-resort technique was forced upon the research. This limitation is the first example of an important point: in order to achieve efficient poverty alleviation using the methods proposed in the present paper, substantially more data is needed for the unique economic, social, environmental, and other variables explored in this model.

The use of 90% confidence over the standard 95% confidence commonly used is an important limitation to discuss. It is true that the parameter estimate results in this model are weaker than they should be in scientific analysis. However, there is also significant weight to the argument that any improvement in some of the variables in this model would provide some relief to Sierra Leoneans. For example, it would be reasonable to infer that improving access to fresh water would improve the livelihood for some Sierra

Leoneans. Additionally, these estimates are still accurate to 90% confidence; they are likely good ballpark starting estimates that policy makers can consider.

An additional limitation of the present research is the potential existence of bias in the model. Omitted variable bias, bias created by excluding variables that explain HDI, inevitably exists in this model. Whether the effects of this bias are large or small, it is important to note that attempting to create a simple model for a complex situation, such as poverty in Sierra Leone, is bound to exhibit at least a small amount of bias. Research has attempted to minimize this bias as much as possible through careful modelling methods, but even the present model has room for improvement.

A variable for education was intended to be included in this model as well, following the presumption that increasing education enhances livelihood. Unfortunately, insufficient and inconsistent data for education persist in Sierra Leone, and thus the variable was neglected in this analysis.

Illegal fishing activity is another important element of analysis that was not included; again, data was insufficient. It can be inferred that data representing illegal fishing is not clearly measured, as these activities are intentionally hidden and secretive. Nevertheless, research suggests that illegal fishing can negatively influence livelihoods (MFMR-SL 2017; Thorpe, et al. 2009), and that illegal fishing is common in Sierra Leone (Agnew, et al. 2009). This variable can very likely have a significant impact on HDI, yet it was beyond the scope of this paper to include it.

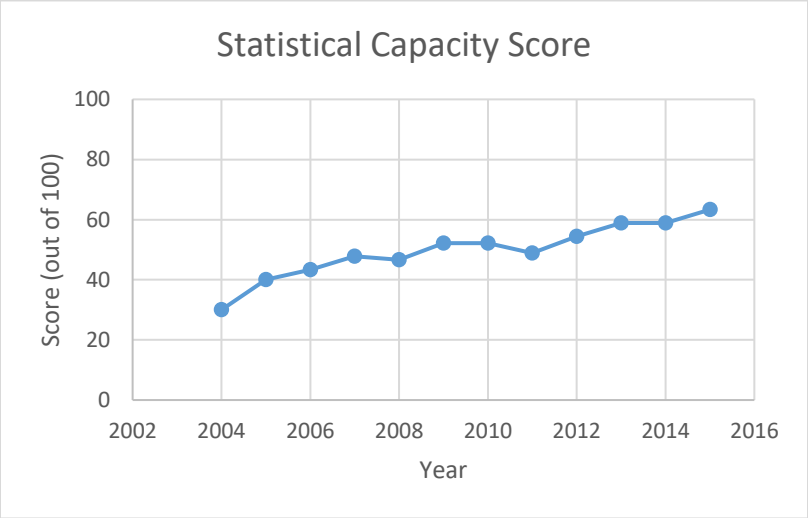

Figure 1: Statistical Capacity Score for Sierra Leone

Notice that the score is consistently low for over a decade. A small increase can be observed, but the values of the score remain low throughout these years (2004-2015).

Data from (FAO n.d.)

Education and illegal fishing are not the only variables to suffer from lack of data. In fact, a number of important variables were not included due simply to the inability to compile data specific to Sierra Leone. Moreover, even the datasets that were used in this research were of insufficient scale to provide a truly robust analysis of a complex Sustainable Livelihoods model. Through extensive research on Sierra Leone, this paper argues that this lack of data may be a result of Sierra Leone's poor statistical capacity score (Figure 1). This score provides a measurable representation of Sierra Leone's ability to successfully collect and analyze accurate and useful data within its country. Sierra Leone data is characterized by sparseness and inconsistency, both of which are revealed in its low score.

Insufficient data has proven to be the "Achilles' heel" of the present research, and thus this paper serves as a call for action in academia. Low-income countries such as Sierra Leone are stricken with poverty and

in dire need of poverty alleviation research and significant data collection. They are clearly unable to perform this data collection for themselves, as the statistical quality of Sierra Leone relates (Figure 1). Poverty alleviation research is a developed field, but in order for current research to continue to improve its effectiveness, it must account for the full set of exogenous elements of society that may affect poverty. This paper has proposed the Sustainable Livelihoods approach as a means to capture these elements, but this approach can only be truly concrete if sufficient data is employed. Therefore, policy makers can only reap the complete benefits of the Sustainable Livelihoods approach to poverty alleviation if future researchers are motivated to collect data in places like this, where quality data collection is a rare, yet necessary commodity; this paper intends to inspire such motivation.

VII. Appendices

Appendix A

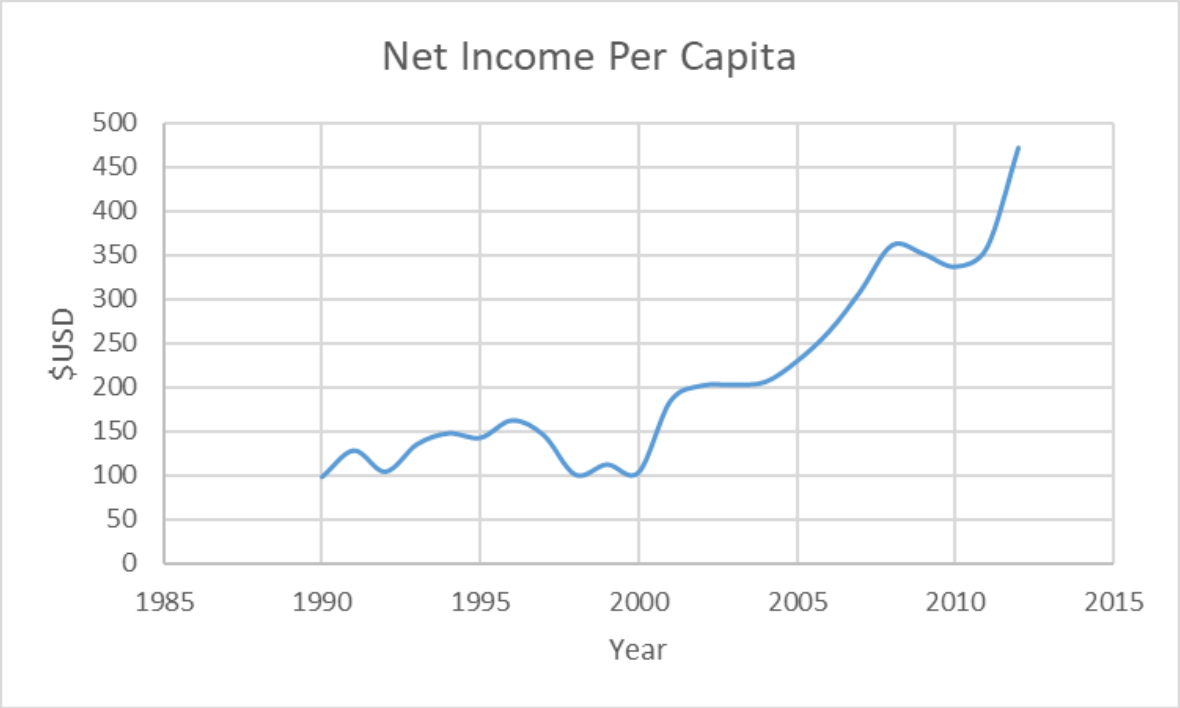

Figure 1A:

Notice the exponential tendency of the data. Also, note the increase in variability of observations as the data increases. These two observations justify the natural log of the data to be used.

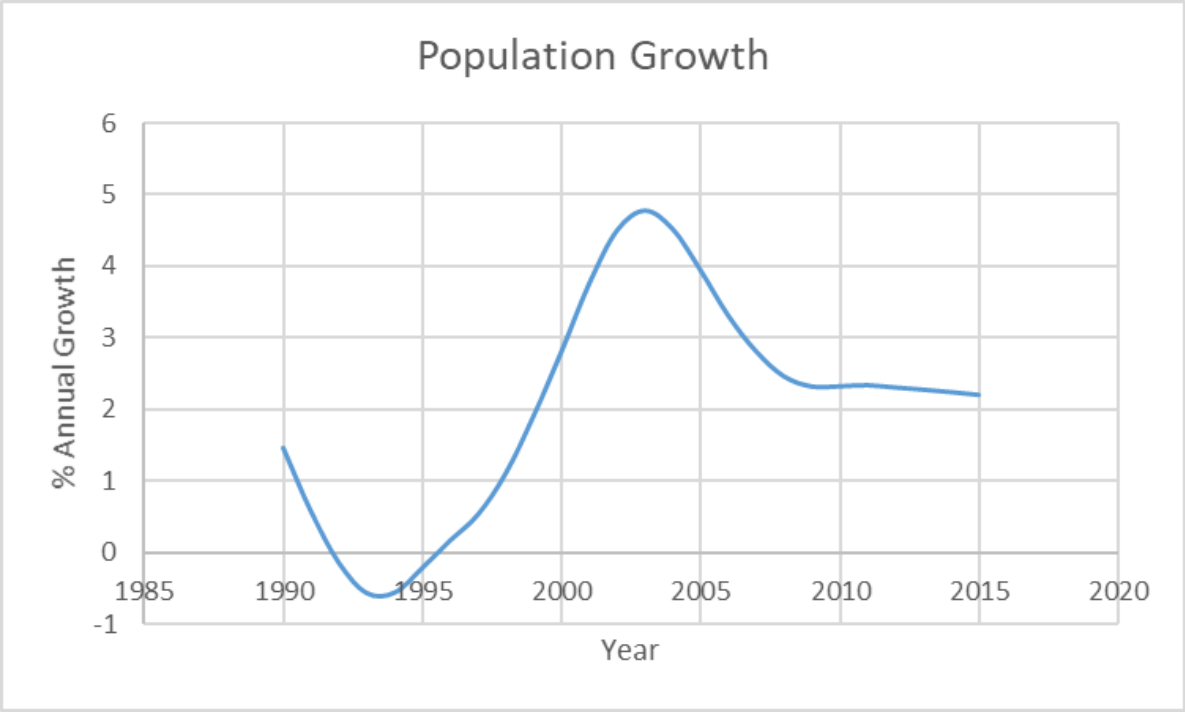

Figure 2A:

Note the population growth of Sierra Leone over time—fluctuations are clearly present.

Appendix B

β	Variable	Abbreviation
1	Marine fish production (tonnes)	marfishprod
2	Aquaculture production (tonnes)	aqua
3	Natural log of adjusted net national income per capita ($USD)	ln_netincomepc
4	Employment to population ratio	employpopr
5	Contributing family workers (% of family)	famworkers
6	Total fisheries production (metric tonnes)	totfishprod
7	Economic Freedom Index	EFI
8	Political stability index	polstab
9	Access to improved water sources (% of population)	accesswater
10	Post-civil war data (dummy variable)	PostCivil
11-14	Missing observations (dummy variables)	missing_

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