Tourism Flows and Marine Biodiversity in Small Island Developing States (SIDS): Evidence from Panel Data.

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Abstract

"One touch of nature makes the whole world kin" (Troilus and Cressida, Act III, Scene III)

Tourism plays a major role in the economic life of most Small Island Developing States (SIDS). This paper uses panel data techniques to investigate the relationship between marine biodiversity and tourism demand in SIDS. Marine biodiversity enters into the analysis through the use of an adapted DPSIR framework. Empirical relationships are estimated that link SIDS tourism demand to the state of biodiversity, existing pressures upon these resources, and policy responses to these pressures, with climate change identified as a major pressure on existing biodiversity. Marine biodiversity indicators are constructed based on the focal areas and headline indicators of the Convention for Biological Diversity. Estimation is based on the Hausman-Taylor Estimator, which allows for the existence of time-invariant and rarely-changing environmental variables, and introduces the issue of simultaneity and feedback effects by through endogenous covariates. Finally, tourism impacts of biodiversity changes are extrapolated to GDP impacts with the estimation of a second-stage panel data regression. This mechanism allows a quantification scheme for baseline values of the benefits/services of marine biodiversity to SIDS, therefore allowing an assessment of the relative magnitude that is provided by marine ecosytem services to the welfare of the local SIDS economies.

1. Introduction

From a development perspective, the world has long since been divided into the dual categories of "developed economies" and "developing countries", with most of the world's biodiversity "hotspots" to be found in the "developing world" (Myers et.al 2000). However, Developing Countries" as a category cannot be seen as an homogenous group, and to treat them as such is to over-simplify the issue (Human Development Report 2007/2008, UNDP 2007). There exists within this group a series of sub-classifications of countries that naturally form based on a confrontation of similar developmental challenges due to common geographical, economic and environmental characteristics. In recognition of this fact, the U.N. Developmental Agenda identified the four overlapping categories of Africa, Least Developed Countries, Small Island Developing States, and Landlocked Developing Countries (U.N. Desa 2007).

Small Island Developing States (or SIDS) have emerged as a distinctive class in the area of environmental studies (Brookfield, 1990, Hein 1990), and one in which global biodiversity is most in danger (Global Environment Outlook 2003). Geographically, the SIDS are spread across the continents of Africa, Asia, and Latin America and the Caribbean (LAC); a 2008 UN Report classified 51 states into the SIDS category (see Appendix 1). SIDS generally share a number of economic and environmental characteristics that combine to make the issues of sustainable resource management particularly crucial in the context of sustainable livelihoods and human well being (Teelucksingh and Nunes 2010, Teelucksingh and Perrings 2010).

The underlying characteristic of SIDS is that of vulnerability. Small populations are coupled with high population densities, concentrated in coastal zone areas which comprise much of the small land areas. An inevitably high ratio of coastal to total land area means that island ecosystems are frequently characterized as 'fragile', with a delicate balance existing between highly coupled terrestrial and marine ecosystems (McElroy et al. 1990). They are also known to be extremely vulnerable to environmental degradation (van Beukering et al. 2007), both in terms of endogenous shocks as ecosystem changes occur, as well as exogenous environmental shifts caused by natural disasters and climate change impacts. There is a heavy reliance on natural resource exploitation, with many of the SIDS being "monocrop", tourism-oriented economies. SIDS are highly vulnerable to the natural environment, in particular natural disasters and climate change impacts. They also exhibit a high degree of economic vulnerability to the world economy due to a dependence on international trade for the absorption of exports and as a source of imports.

Due to geographical advantage, marine and coastal habitats play a particularly important role in SIDS. For many small islands the marine environment can be the most important economic resource (Bass 1993). It is commonly accepted that the marine resources available to island states can, if properly utilised, significantly contribute to the sustainable development of the region (Dolman 1990). While provisioning services through fisheries resources are particularly important to local communities, a geographic advantage in marine habitat has led to tourism (and, increasingly, eco-tourism) playing significant roles in island economies (Teelucksingh and Perrings 2010).

In recognition of the role of biological diversity in these types of industries, the Convention on Biological Diversity recognises tourism and eco-tourism as important tools for the promotion of biodiversity conservation and sustainable livelihoods (Honey 2006). Biodiversity is a crucial component of local livelihoods in SIDS, with marine and coastal biomes in particular contributing significantly to food security and income via their role in the provisioning services of capture fisheries and the tourism /eco-tourism industries (Teelucksingh and Perrings 2010). Interestingly, Teelucksingh and Nunes (2010) review the existing literature on biodiversity valuation and ecosystem services in SIDS and find studies for only 17 out of the 51 SIDS nations.

Biodiversity change affects human wellbeing through the effect it has on the flow of ecosystem services. In SIDS this may be measured by the marginal impact of biodiversity change on these industries. It is therefore necessary to empirically investigate the linkages between biodiversity and tourism demand, in an effort to assess the magnitude that the protection of biodiversity, and the sustainable provision of ecosystems goods and services, can provide to local welfare.

The rest of this paper is structured as follows: in the following section, we construct a variable set within a theoretical DPSIR model framework. Section 3 populates these variables with data, identifting sources, challenges and limitations in so doing. Section 4 using a framework of DPSIR. Section 5 considers the empirical results. Section 6 extends these results to GDP impacts which can be seen as indicative of welfare changes. Section 7 concludes.

2 A Theoretical Framework

Traditional tourism demand models identify a host of determinants of such demand. These include economic, demographic, sociological and other variables. See Soon and Li (2008) for a comprehensive review. The model used may be derived from a twice-separable utility function. Though the range of explanatory variables varies widely, few studies, notably Macagno and Nunes (2010) and Macagno et al (2009) attempt to include biodiversity related variables among them. In this paper, biodiversity related variables are emphasised in an effort to explain tourism demand in SIDS, with a general model formulated as:

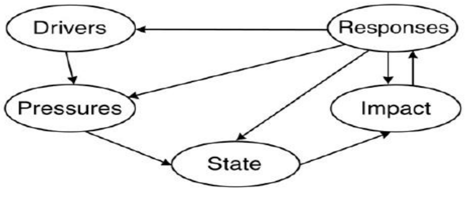
$$td = \mathrm{f}(mml, mpa, temp, coral, end, kba, ra, y, u)$$

with
td = tourism demand
mml = mean maximum length of fisheries catch
mpa = marine protected areas
$temp$ = temperature
$coral$ = coral reef acreage
end = abundance of endangered species
kba = number of key biodiversity areas
ra = relative abundance of species
y= Economic activity
u = Other (unobservable) variables

What do we expect the effects of each of these variables to be on tourism demand? The *mml* variable is a proxy for marine ecosystem health and declining levels would provide evidence that there is "fishing down the food chain", synonymous with loss of marine biodiversity higher up the food web and therefore an indication of declining ecosystem health. This is therefore expected to be positively related to tourism demand. Marine Protected Areas, as a percentage of territorial waters, would be expected to have a positive impact on tourism demand. In the case of the two indicators of species abundance, *ra* and *end*, an increase in *ra* is expected to lead to an increase in tourism demand. To the extent that the number of endangered species is an indicator of existing biodiversity, then positive changes in this should have a negative impact on tourism demand. However, another possibility is that, as numbers of endangered species increase, this may act as a pull-factor to international tourists. Finally, a positive relationship might be expected between tourist demand and the one climate variable, temperature, since tourists from the colder, richer countries are likely to seek warmer temperatures. However, rising temperatures may also act as a push rather than a pull factor, resulting in a negative relationship. The variable *y* is expected to be positively related to tourism demand since tourists are more likely to be attracted to countries with higher living standards (and, arguably, better infrastructure) than to poorer countries.

Variables appearing in this model may be interpreted as representations of different aspects of biodiversity-related, environmentally-related and economic decisions within a DPSIR framework. The Millennium Ecosystem Assessment identifies the most important direct and indirect drivers on biodiversity and ecosystem services to be habitat change, climate change, invasive species, over-exploitation and pollution, with the driving forces behind such pressures categorised into demographic, economic, socio-political, cultural, religious and scientific/technological changes (Millennium Ecosystem Assessment [3] 2005, Omann et.al 2009). It is important to place such drivers of biodiversity change within a framework that recognizes the linkages and feedbacks within socio-ecological systems, and that connects the drivers, their impacts on human welfare at all spatial scales, and the policy responses to these impacts to standardised national and global biodiversity indicators. One such methodology is the DPSIR Framework. Figure 1 below provides a schematic outline of the DPSIR model.

Figure 1: The DPSIR Model



Source: Maxim et.al (2009)

The DPSIR methodology seeks to embed environmental challenges within a socio-economic framework (Maxim et.al 2009, Rodriguez-Labajos et.al 2009, Ness 2010). Societal developments or *Drivers* cause *Pressures* to be exerted upon environmental resources, which result in changes in the *State* of resources.

Such changes lead to *Impacts* on human wellbeing through impacts on ecosystems. Depending on the magnitude of these impacts, this can cause policy *Responses* at different levels of spatial scale. These five interlinked parameters do not, however, occur in a linear, deterministic fashion; on the contrary, there may exist multiple links. In this context, Teelucksingh and Perrings (2010) categorise biodiversity indicators of SIDS using an adapted DPSIR framework with the 4 focal areas of Pressures-Threats, Status-Trends, Benefits-Services and Actions-Responses.

Following this framework, it is possible to frame all of the model variables into these categories, as in Table below. In a developing country context, the notion of human wellbeing and the distribution of the benefits of biodiversity resources through their supply of ecosystem services, or the benefit-sharing component of the ecosystem services provided by the biodiversity resources, is a crucial one. Addressing the question of the role of biodiversity in the productive economic sectors in developing countries is a key aspect of this, as the provisioning services – foods, fuels, fibers etc – are critical to employment and incomes. This requires indicators that link biodiversity change to changes in ecosystem service flows, and hence to the wellbeing of both producers and consumers (Teelucksingh and Nunes 2010). Linking changes in biodiversity to impacts upon tourism demand can do just that. By selecting a dependent variable that can be categorised within Benefits-Services, by specifying this variable as a function of existing Status-Trends as well as current Actions-Responses, and by formulating the links of these regressor variables to Pressures-Threats, it is possible to quantify the DPSIR framework, with the resultant quantification of welfare changes due to the loss of ecosystem services as a result of biodiversity loss.

Table 1: Variable List within a DPSIR Framework

Temperature	Pressures-Threats
Coral reef Acreage	Status-Trends
Abundance of Endangered Species	Status-Trends
Relative abundance of species	Status-Trends
Mean Maximum Length	Status-Trends
Economic activity	Status-Trends
Marine Protected Areas	Actions-Responses
Key Biodiversity Areas	Actions-Responses
Tourism Demand	Benefits-Services

Adapted from Teelucksingh and Perrings (2010)

What is the benefit of framing the variables in this manner? Most importantly, such a framework points to the inter-dependence among these variables. Changes may manifest themselves in these variables over time as a result of a single policy decision (environmental or economic) or set of decisions. The framework employed sheds some light on policy paths towards environmental conservation. In addition, given that these variables all impact upon tourism demand, the economic impact of these environmental policy paths can also in some way be estimated.

The Status-Trends variables, identified here as *y*, *fc* (an indicator of marine ecosystem health) *coral* (indicator of coral reef size), *ra* (relative species abundance) and *end* (abundance of endangered species). The last two are both indicators of current status as well as target indicators for which policy action can be constructed. The Actions-Responses variables (defined here as *mpa* and *kba*) define the policy options available both in terms of a response to current status-trends and the ways in which these current status-trends can be impacted.

The major Pressure-Threat of marine biodiversity change in SIDS is identified here as climate change (Teelucksingh and Perrings 2010). The IPCC explicitly recognises this fact; in particular, it is recognised that SIDS are characterised by ecosystems that are vulnerable to climate change (IPCC 2002). As small islands, climate change can have significant direct and indirect effects on economic and social systems from impacts on marine ecosystems; for example, from the erosion of coastal zones due to sea-level rise, to the effects of warming seas on coral reef ecosystems upon whose services many local livelihoods depend through coral reef fisheries and tourism activities, to the effects of increased frequency and severity of tropical storms. Climate change is considered to be one of the greatest threats to coral reef ecosystems, with mass coral bleaching due to increasing sea temperatures and ocean acidification responsible for much of the present loss of coral cover (Brander et al. 2007, Obura and Grimsditch 2009). In terms of fisheries resources, climate change directly affects the distribution of species, the seasonality of specific biological processes and the structure of existing food webs (Ewinger et.al 2009). Climate change can also raise the risk level of species invasions (Ewinger et.al 2009)., and there is evidence that climate change can be linked to species losses (IPCC 2002). Underlying this is the inability of SIDS to meaningfully affect climate changes – small islands can be considered “environment-takers”, only able to react and mitigate to global levels. In this context, and in line with the approach of Teelucksingh and Perrings (2010), climate change is hypothesized as a major driver of change within which all biodiversity indicators may be interpreted.

Finally, the remaining category of Benefits-Services brings into question the complex concept of “human well being” and, in the context of this category, the contribution of ecosystem goods and services to human well being (Teelucksingh and Perrings 2010). The *mpa* presents a comprehensive overview of the factors that both comprise and affect the state of human wellbeing, constructing a framework in which both the direct and indirect linkages of these factors to biodiversity and ecosystem services are presented. The hypothesis is that drivers of change impact upon ecosystems and the goods and services they provide, thus affecting human wellbeing. If we are able to define these linkages quantitatively or qualitatively, the impacts upon human well being of decisions that affect biodiversity and ecosystems at any level of spatial scale can then be mapped. In addition, we may theorise as to a number of “feedback” loops: that the supply of ecosystem services themselves can impact the drivers of change, that the state of human wellbeing itself can affect ecosystem services via the increases or decreases of demands placed on these services, and that human wellbeing is directly linked to the drivers of change.

Given this theoretical model construction, we now turn our attention to the data needs of such a model.

3 The Data: Availability, Challenges and Limitations

The theoretical model derived above requires a database assemblage on four fronts: tourism, economic, environmental and climate change data. All data used are annual.

Tourism demand is often proxied by tourism arrivals, which is the choice of this paper. Other possible choices are tourism expenditure, tourism revenues, and tourism employment (Song and Li 2008).Tourism data was captured from the online database of the World Travel and Tourism Council (http://www.wttc.org/eng/Tourism_Research/Economic_ Data_Search_Tool/index.php) as well as from the online UN databases at http://data.un.org/Document Data.aspx?id=168. With a focus on tourism international arrivals to the SIDS destinations, and variables such as capital investment in the industry and employment created, the ultimate tourism dataset consisted of data for the period 1988 to 2010. Economic data was obtained from the online databases of the World Bank and consisted of routine economic variables such as GDP, GDP per capita over the period 1988 to 2008. Climate change data consisting of variables such as cloud cover, temperature and precipitations for the period 1988 to 2009 was obtained from the online databases of the Tyndall Centre.

The biodiversity-related data presented in this analysis cover coral reefs, marine and protected terrestrial areas, the marine trophic index and related indices, biodiversity species indicators, and numbers of alliance for zero extinction (AZE) and key biodiversity areas (KBA) sites.

Data on coral reefs as percentage of world totals were obtained from the "Sea Around Us" website (www.seaaroundus.org), with data available for all SIDS. Rather than presenting country specific coral reef estimates, this website presents the fraction of the world's global coral reef area that occurs in the Exclusive Economic Zone of a given country. We use here the global estimates of Spalding et.al (2001), as presented in Wilkinson (2008) to estimate surface areas of coral reef cover in squared kilometres.

All indicators of marine and protected areas come from the World Database of Protected Areas, http://www.wdpa.org/Statistics.aspx . This includes time series data from 1990 to 2009 for (1) the proportion of marine areas protected (percentage of territorial waters up to 12 nautical miles) (2) the proportion of terrestrial areas protected (percentage of terrestrial area) and (3) the proportion of terrestrial and marine areas protected (percentage of terrestrial area and territorial waters up to 12 nautical miles). Data was distilled for 48 SIDS, with no information available on these parameters for Sao Tome and Principe, the Maldives, and Nauru.

The IBA and AZE Protection Indices show trends over time in the protection of areas of particular importance to biodiversity. Detailed IBA data by country can be found at http://www.birdlife.org/datazone/sites/index.html, and country-specific AZEs can be found at http://www.zeroextinction.org/search.cfm . This information is itself summarised in the IBAT database (www.ibat.org), where numbers of IBAs and AZEs per country are presented.

The Red List Index and Sampled Red List Indices measure trends over time in the overall extinction risk of species, as measured by their category of extinction list on the IUCN red list. Data and publications at country level are available on the IUCN website at http://www.iucnredlist.org/about/summary-statistics;

in addition, the IBAT database (www.ibat.org) also summarises this information. We highlight in particular the following categories, for which SIDS data are largely available: the number of threatened species in each major group of organisms in each country (Critically Endangered, Endangered and Vulnerable categories only); the number of extinct, threatened and other species of animals in each Red List Category in each country; the number of extinct, threatened and other species of plants in each Red List Category in each country, and the total endemic and threatened endemic species in each country (totals by taxonomic group).

The Marine Trophic Index (MTI) measures the mean trophic level of fish catches. A related and comparable indicator to the MTI is the Mean Maximum Length (MML). Predation is a key process that shapes marine ecosystems and their structure (Pauly and Watson 2005). Because body size is correlated with mouth size, predator-prey size ratios are generally predictable, with predators usually being 3-4 times larger than their prey (Pauly and Watson 2005). In this context, the trophic level at which fishing occurs, and the length of the landed catch, can be an indication of the status of the biodiversity of the ecosystem from which the landed species come. The assumption is that if fisheries catches consist of increasingly smaller fish or species low in the food web, this is an indication that resources not being sustainably exploited (Pauly 2005). In this context, the MTI and the MML are used as a biodiversity indicators, in particular with reference to the richness and abundance of larger fish species at higher trophic levels (Pauly 2005). If the assumption is made that the relative abundance of taxa in the catch data are representative of the relative abundance of the same taxa in the ecosystem, then declining trends can indicate a decline in the abundance of fishes higher up the food web, therefore indicating a current and potential impact on biodiversity, both in terms of intra-species and inter-species. Data for all SIDS on the MTI and MML can be found at www.seaaroundus.org

This type of analysis is solely dependent upon secondary data. Interestingly, Song and Li (2008) identify this dependence as one of the possible reasons for the heavy “developed world” focus of “empirical analysis” along these lines. Data issues plague developing countries and in many cases act as a severe limitation to empirical work (Naude and Saayman 2005) and this study was no different.

Missing data was the obvious issue in each of the 4 datasets, consequently restricting the empirical analyses. In the tourism databases, data was unavailable for 15 islands, including Guinea-Bissau (Africa), Monsterrat (Caribbean) and 13 Asia/Pacific states. The economic database had no information on Sao Tome and Principe (Africa), Cuba, The Netherland Antilles and the U.S. Virgin Islands (Caribbean), and American Samoa and Guam (Asia/Pacific).

The level of aggregation of some of the data used is also a consideration. The tourism variable used here is the number of international tourist arrivals, therefore not offering the possibility of distinction of country of origin. Furthermore, aggregation in terms of periodicity is a consideration. All analyses in this work takes place at an annual level due to data constraints. In particular, the biodiversity data gathered was only available at annual levels. Many tourism studies use quarterly data to account for seasonal variations – the implicit assumption here is that this study is not able to analyse seasonal trends. Furthermore, climate change data is available at monthly, weekly and sometimes daily levels, due to variability within these time periods. However, we restrict the climate change data used here to annual averages.

The biodiversity dataset is characterised with its own set of limitations. Obtaining data representing marine biodiversity in SIDS was a very challenging task. The measurement of biodiversity through indicators is a burgeoning area, and much data are being routinely collected in the developed but not in the developing world (Teelucksingh and Perrings 2010). With 2010 as the headline year for determining progress to halting trends of biodiversity loss, much attention has been given to the ways in which biodiversity changes can be measured – The Convention on Biological Diversity has identified 17 headline indicators (CBD 2006); the Biodiversity Indicators Partnership has developed a suite of composite indicators along these lines under 7 key focal areas. Butchart et al (2010) calculated values and trends for many of these indicators at a global level in an effort to assess progress towards the 2010 targets. However, many of the indicators are in formative stages only and are not in a position to be universally and quantifiably assessed.

Estimates of surface area covered by corals are embedded within existing and ongoing controversy of issues of definition and issues of scale (the Sea Around Us website). For this reason, the data given is presented as percentages only, with the responsibility then falling to the user to multiply these percentages by their preferred global estimates. Furthermore, once estimates of surface area are obtained in this way, these estimates refer to cover only, without differentiating between types of coral, or giving relative indications as to the health of reef systems.

The declaration of a protected area does not necessarily imply that the area is protected. Nor does it imply that the objectives of protection are fulfilled. The indicators of marine and terrestrial protected areas used here in no way indicate the effectiveness of those protected areas or their management.

There are many criticisms of the use of the MTI, the MML and related indices as an indicator of ecosystem health (Pauly and Watson, 2005). In particular, the sensitivity of these indices to the underlying catch data is vulnerable to the fact that the catch data upon which national statistics may be focused may be inaccurate, and unrepresentative of the abundance of species in the ecosystem. To this end, the Sea Around Us project has undertaken the reconstruction of catch statistics at the country level to reflect the full range of the fisheries of a country. Note that for our 51 SIDS, 11 countries are associated with reconstructed catch data on the project database. A related problem is that of the category of "Miscellaneous Fishes", for which no indices can be calculated - The Sea Around Us data includes the indicator calculations based only on reported taxa.

The Red List Indicator group was developed for the classification of species at risk of global extinction; that is, for assessment at a global level only. However, in sub-global assessments, caution needs to be exercised in the use of Red List indicators. Furthermore, if as in the case of a SIDS analysis we are restricting the discussion to marine indicators, then using Red List information at a country level may be misleading. A species at risk in many countries may not be at risk at the level of a particular small island state. In recognition of such limitations, and the need for sub-global indicators, The IUCN presents guidelines for the development of regional/national indicators at http://www.iucnredlist.org/documents/reg_guidelines_en.pdf, and presents sub-global (regional and national) information at http://www.regionalredlist.org . However, there exists no information for any of our 51 SIDS here, restricting us to the use of the published global indicators at country level, while remaining cognizant of the limitations of so doing.

Given the assemblage of this data set for SIDS, we now turn our attention to the empirical estimations.

4 Empirical Estimations

Panel data techniques are employed, allowing for the capture of both space and time effects. Compared to cross sectional or time series studies, panel data analysis permits the investigation of spatial effects that may be particularly relevant in studies that involve multiple locations. The presence of time invariant and rarely-changing variables is a common challenge in panel data analyses and, while it is possible to include such variables in Random Effects models, the more rigorous Fixed Effects models do not allow for it Time invariant variables are particularly a problem in environmental datasets. While some environmental data (such as climate change indicators of precipitation and temperatures) are available at high levels of frequency, others (such as coral reef size and acreage, sites designated as biodiversity areas, mangrove size, and indicators of species extinction) may for all intents and purposes be considered time invariant within the types of time periods of analyses that are conducted. In addition, some environmental data may only be available for a snapshot of time or for fixed, non continuous points through a period of time. The inability to include such data in empirical analyses that do not allow for time-invariant or rarely changing variables is a significant limiting factor, and one that may lead to inherent model misspecifications which, owing to methodological constraints, may be unable to be corrected.

Two panel estimation techniques that allow for fixed-effects estimation in the presence of time invariant variables are the Fixed Effects Vector Decomposition (FEVD) and the Hausmann-Taylor (HT) Estimator. The Fixed Effects Vector Decomposition (FEVD) estimator (Plümper and Troeger 2007) has, in recent times come under severe criticism from some quarters. Breusch et al (2010), in particular, declare that "the three-stage procedure of this decomposition is equivalent to a standard instrumental variables approach, for a specific set of instruments" and that "the estimator reproduces exactly classical fixed-effects estimates for time-varying variables" and, finally, that the "reported sampling properties in the original Monte Carlo evidence are incorrect." Compared to the FEVD estimator, the HT estimator, as an instrumental variable estimator, has the added boon of the ability to estimate in the face of declared endogenous explanatory variables. This allows for an added level of investigation, where in a structural, dependent versus independent variable setting we have the ability to allow for inter-dependence among these variables.

The specific form of the model estimated here is

$$ta_{\mathbf{i,t}}=\alpha+\beta_1 mml_{i,\,t}+\beta_2 mpa_{i,\,t}+\beta_3 temp_{i,\,t}+\beta_4 gdp_{i,t}+\beta_5 coral_{i,t}+\beta_6 end_{i,t}+\beta_7 kba_{i,t}+\beta_8 ra_{i,t}+u_{i,t}$$

where
ta = international tourist arrivals
mml = mean maximum length of fisheries catch
mpa = marine protected areas
temp = temperature
gdp = gross domestic product
coral = coral reef acreage
end = abundance of endangered species
kba = number of key biodiversity areas
ra = relative abundance of species
u = Other (unobservable) variables

Now, the dependent variable is specified specifically as international tourism arrivals to the SIDS, and economic activity is proxied specifically by destination country GDP. All variables are in logarithmic form.The index i refers to the country and the index t refers to the year when the observation was made. Estimation is done using the Hausman-Taylor estimator, which allows for the incorporation of time-invariant variables, of which there are four in this model (*ra*, *end*, *kba* and *coral*). The endogenous covariate is *gdp*. The dependent variable is expected to respond positively to a positive change in each of the explanatory variables, except that there is some ambiguity attached to the *temp* and *end* variables, which could respond in the opposing direction (see above).

The results obtained from application of the H-T estimator are shown in Table 3 below:

Table 3: Coefficient Estimates

Explanatory Variable	**Estimated Coefficients**
mml	0.260***
mpa	0.114***
gdp	1.545***
temp	1.216
coral	-0.988***
end	1.871***
kba	1.243***
ra	0.755
Constant	-8.312*

Wald χ^2 *= 418.26 (p-value=0.000)*
**** significant at the 1% level, * significant at the 10% level*

The overall fit of the model is exceptionally good given the high value of the Wald statistic and its asscoaited p-value, which is close to 0. Two variables (*temp* and *ra*) are not significant at accepted levels but all the others are highly significant (lwer than 1% in all cases).

The model is re-estimated after removal of the insignificant variables and the following results, shown in Table 3, are obtained:

Table 3: Coefficient Estimates

Explanatory Variable	EstimatedCoefficients
mml	*0.255****
mpa	0.118***
gdp	1.601***
coral	-0.981**
end	1.911***
kba	1.232***
Constant	-7.443**

Wald $\chi^2 = 406.7$ *(p-value=0.000)*

****significant at the 1% level, ** significant at the 5% level*

There is no marked change in the results: once again, the fit is very good, based on the high value of the Wald statistic (and its correspondingly low-p-value). All variables are significant at the 1% level except *coral*, which is significant at the 5% level. The *coral* variable also has a negative sign, which is unexpected, while all other variables have the expected (positive) sign.

How may the sign on the *coral* variable be explained? There are (at least) three possible explanations. First, it is a possible that this positive sign is alluding to a tourism preference for pristine rather than highly-exploited reef systems in SIDS; islands with high reef acreage may be assumed to be also characterised by high visitor intervention in the ecosystems. Second, as an indicator of ecosystem health, coral reef acreage on its own, without indications as to types of coral or health of the systems, may not be the most robust choice of explanatory variable. In addition, if coral reef acreage is expected to change in accordance with marine ecosystem health, the fact that we can only use this variable as a time-invariant specification may be a strong limiting factor and, even if a time series variable were available, the period over which this would have to occur in order to reflect ecosystem changes may be extremely long. Third, it could be that increasing tourism may have negative impacts on the environment through improper sewage and waste disposal in coastal zones. If this variable impacts upon tourist arrivals, tourist arrivals may in turn impact upon it.

The variables used in this model are a combination of time-variant and time-invariant data. Specifically, the time-invariant variables include coral reef acreage, numbers of key biodiversity areas, and the two indicators of relative abundance and endangered species. The question then becomes, which of these variables can actually be considered time-invariant, and which were simply constrained to be so due to lack of regular environmental data collection and monitoring in SIDS? Coral reef acreage is expected to change minimally over short time periods, so the assumption of time-invariance here is a reasonable one, though over longer term time periods we would expect data to indicate some shifts. We would expect that key biodiversity areas change in the short term, as a reflection of short-term policy decisions. Similarly, we would expect that relative abundance and endangered species would change over the medium term (though not the short term). However, data monitoring and calculation of these indicators and statistics is not yet a routine function. The implication of this is that, by specifying these variables as time-invariant (and we are left with no choice but to so do), we may have inherent model misspecification that could lead to a distortion of empirical results, once again begging caution in the interpretation of all results.

5 Quantifying Welfare Changes

What is the impact of biodiversity change on general economic activity, via its effect on tourism demand? This may be determined using the following model::

$$gdp_{i,t}= \phi+\gamma\, ta_{i,\, t} + e_{i,t}$$

This model is fitted using, first, a Fixed Effects, then a Random Effects model, then the Hausman Test is used to choose between the two. These results are shown in Appendix 3. The test shows that the Fixed Effects model is to be preferred. The elasticity of tourism arrivals with respect to GDP is therefore estimated at 0.195% and it is highly significant. This result is used to extrapolate the percentage impact of each variable on tourism arrivals to the percentage impact of each variable on GDP. Table 4 below summarises these results.

Table 4: Percentage Impacts upon *gdp* of a 1% change in Environmental Variables

Environmental Variable	% Impact on *ta*	% Impact on *gdp*
mml	0.255	0.0724
mpa	0.118	0.0335
coral	-0.981	-0.2786
end	1.911	0.5427
kba	1.232	0.3499

Within the DPSIR framework, these results facilitate the calculation of the effects of policy actions(or policy inaction) upon economic activity in SIDS via their impacts on tourism flows. For example, the impacts of policy Actions-Responses on livelihoods may be determined, for example, a 1% increase in Key Biodiversity Areas in an island will, from these results, cause a 0.34% increase in GDP due to increased tourism; similarly, a 1% increase in Marine Protected Areas in an island's territorial waters will cause a 0.035% increase in GDP. In addition, the effects of exogenous shocks may be measured using these ratios; for example, if climate change causes exogenous changes to biodiversity-related variables, those changes may be extended to changes in livelihoods due to changes in tourism arrivals.

This may be quantified into dollars and cents at any point in time by applying these percentages to actual or forecasted GDP for any individual SIDS territory, for any aggregated subset of SIDS or for the total SIDS category as a whole. In addition, by applying relevant population estimates, these values may be converted into per capita costs or benefits. As an example, we calculate for 2008 the estimated GDP changes due to a 1% change in each of the environmental regressors (see Appendix 4); we also calculate these changes in per-capita terms (see Appendix 5). These results are summarized by region in Tables 5 and 6 below. These figures are based on the assumption of 2008 GDP figures and are therefore conditional upon that figure. However the percentages in Table 4 above may be applied to any forecasted GDP. Furthermore, this mechanism permits the estimation of the impacts upon SIDS that were due to data constraints, not included in the estimation sample. In this way, we are able to suggest a quantification scheme for baseline values of the benefits of marine ecosystem services to SIDS.

Table 5: Aggregate Effects on 2008 GDP by Region
(US Millions, Constant Prices 2000)

	MML Impact	MPA Impact	CORAL Impact	END Impact	KBA Impact	TOTAL
AFRICA	584.41	270.43	-2248.25	4379.62	2823.49	5809.70
CARIBBEAN	5203.69	2407.98	-20018.89	38997.04	25140.95	51730.77
ASIA / PACIFIC	10507.53	4862.31	-40423.07	78744.64	50765.78	104457.18
TOTAL SIDS	**16295.62**	**7540.72**	**-62690.21**	**122121.30**	**78730.22**	**161997.65**

Table 6: Aggregate Effects on 2008 GDP Per Capita by Region
(Constant Prices 2000)

	MML Impact	MPA Impact	CORAL Impact	END Impact	KBA ImpactC
AFRICA	1094.233	506.351	-4209.580	8200.313	5286.649
CARIBBEAN	4782.678	2213.161	-18399.243	35841.951	23106.899
ASIA / PACIFIC	3776.216	1747.425	-14527.323	28299.403	18244.304
TOTAL SIDS	9653.127	4466.937	-37136.146	72341.667	46637.851

According to 2008 estimates, the aggregate impact of a 1% change in biodiversity variables on all SIDS is $161 997.65 USD million, with the Asia/Pacific region bearing the most of this cost.

6 Conclusion

This paper used panel data techniques to investigate the relationship between marine biodiversity and tourism demand in Small Island Developing States. Variables were assembled that relate to tourism, biodiversity, and state of the economy of SIDS. The biodiversity variables in particular posed a challenge, due to (1) the formative stages of biodiversity indicators and (2) the lack of routine collection of environmental variables in developing countries. Where such information existed, marine biodiversity indicators were constructed based on the focal areas and headline indicators of the Convention for Biological Diversity. The empirical estimation was framed within an adapted DPSIR framework, where relationships were theorized and estimated that linked SIDS tourism demand to the state of biodiversity, existing pressures upon these resources, and policy responses to these pressures, with climate change identified as a major pressure on existing biodiversity. Estimation was based on the Hausman-Taylor Estimator, which allows for the existence of time-invariant and rarely-changing environmental variables, and introduces the issue of simultaneity and feedback effects by through endogenous covariates. Finally, tourism impacts of biodiversity changes were extrapolated to GDP impacts with the estimation of a second-stage panel data regression. This mechanism allowed, ultimately, a quantification scheme for baseline values of the benefits/services of marine biodiversity to SIDS, therefore allowing an assessment of the relative magnitude that is provided by marine ecosystem services to the welfare of the local SIDS economies.

Appendix 1: The U.N. List of SIDS

(source: UN DESA 2007)

AFRICA
Cape Verde
Comoros
Guinea-Bissau
Mauritius
Sao Tome & Principe
Seychelles

CARIBBEAN
Anguilla
Antigua and Barbuda
Aruba
Bahamas
Barbados
Belize
British Virgin Islands
Cuba
Dominica
Dominican Rep
Grenada
Guyana
Haiti
Jamaica
Montserrat
Netherlands Antilles
Puerto Rico
St. Kitts and Nevis
St. Lucia
St. Vincent & Grenadines
Suriname
Trinidad and Tobago
Virgin Islands, U.S.

ASIA / PACIFIC
American Samoa
Commonwealth of Northern Marianas
Cook Islands
East Timor
Fiji
French Polynesia
Guam

Kiribati
Maldives
Marshall Islands
Micronesia (Federated States of)
Nauru
New Caledonia
Niue
Palau
Papua New Guinea
Samoa
Singapore
Solomon Islands
Tonga
Tuvalu
Vanuatu

Appendix 2: STATA Regression Results

```
xthtaylor ln_TA ln_gdp ln_MML ln_MPA ln_CORAL ln_END ln_KBA ln_RA ln_TEMP, end(ln_gdp)

Hausman-Taylor estimation                       Number of obs      =       202
Group variable: id_country                      Number of groups   =        14

                                                Obs per group: min =         6
                                                               avg =      14.4
                                                               max =        17

Random effects u_i ~ i.i.d.                     Wald chi2(8)       =    418.26
                                                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
       ln_TA |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
TVexogenous  |
      ln_MML |   .2595681   .0751979     3.45   0.001     .1121828    .4069533
      ln_MPA |   .1144194   .0172837     6.62   0.000     .0805441    .1482948
     ln_TEMP |   1.216363   1.163698     1.05   0.296    -1.064444     3.49717
TVendogenous |
      ln_gdp |   1.544588   .1075512    14.36   0.000     1.333791    1.755384
TIexogenous  |
    ln_CORAL |  -.9881194    .363531    -2.72   0.007    -1.700627   -.2756117
      ln_END |   1.871424   .4491791     4.17   0.000     .9910489    2.751799
      ln_KBA |   1.243082   .4165056     2.98   0.003     .4267457    2.059417
       ln_RA |   .7550532   .5471836     1.38   0.168    -.3174069    1.827513
             |
       _cons |  -8.311995   4.858603    -1.71   0.087    -17.83468    1.210693
-------------+----------------------------------------------------------------
     sigma_u |    .828187
     sigma_e |  .15103062
         rho |  .96781414   (fraction of variance due to u_i)
------------------------------------------------------------------------------
Note:  TV refers to time varying; TI refers to time invariant.
```

```
xthtaylor ln_TA ln_gdp ln_MML ln_MPA ln_CORAL ln_END ln_KBA, end(ln_gdp)


Hausman-Taylor estimation                       Number of obs      =       202
Group variable: id_country                      Number of groups   =        14

                                                Obs per group: min =         6
                                                               avg =      14.4
                                                               max =        17

Random effects u_i ~ i.i.d.                     Wald chi2(6)       =    406.74
                                                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
       ln_TA |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
TVexogenous  |
      ln_MML |   .2545943   .0748333     3.40   0.001     .1079237    .4012649
      ln_MPA |   .1177982   .0169995     6.93   0.000     .0844798    .1511165
TVendogenous |
      ln_gdp |   1.606643   .0974845    16.48   0.000     1.415577    1.797709
TIexogenous  |
    ln_CORAL |  -.9812762   .4815634    -2.04   0.042    -1.925123   -.0374293
```

```
      ln_END |   1.914952   .5020348     3.81   0.000     .9309821    2.898922
      ln_KBA |    1.23206   .4853807     2.54   0.011     .2807316    2.183389
             |
       _cons |  -7.442566   3.679051    -2.02   0.043    -14.65337   -.2317596
-------------+----------------------------------------------------------------
     sigma_u |  .92156017
     sigma_e |  .15139068
         rho |  .97372238   (fraction of variance due to u_i)
------------------------------------------------------------------------------
Note:  TV refers to time varying; TI refers to time invariant.
```

Appendix 3: Hausman Test Results

Fixed Effects Model

```
Fixed-effects (within) regression               Number of obs      =       637
Group variable: id_country                      Number of groups   =        35

R-sq:  within  = 0.4273                         Obs per group: min =         6
       between = 0.3208                                        avg =      18.2
       overall = 0.3643                                        max =        21

                                                F(1,601)           =    448.38
corr(u_i, Xb)  = 0.3435                         Prob > F           =    0.0000

------------------------------------------------------------------------------
      ln_gdp |      Coef.   Std. Err.      t    P>|t|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       ln_TA |   .1950411   .0092109    21.17   0.000     .1769515    .2131306
       _cons |   6.930919   .0490152   141.40   0.000     6.834657    7.027181
-------------+----------------------------------------------------------------
     sigma_u |  .93958614
     sigma_e |  .11739884
         rho |  .98462813   (fraction of variance due to u_i)
------------------------------------------------------------------------------
F test that all u_i=0:     F(34, 601) =   949.48             Prob > F = 0.0000
```

Random Effects Model

```
xtreg ln_gdp ln_TA, re

Random-effects GLS regression                   Number of obs      =       637
Group variable: id_country                      Number of groups   =        35

R-sq:  within  = 0.4273                         Obs per group: min =         6
       between = 0.3208                                        avg =      18.2
       overall = 0.3643                                        max =        21

Random effects u_i ~ Gaussian                   Wald chi2(1)       =    458.78
corr(u_i, X)       = 0 (assumed)                Prob > chi2        =    0.0000

------------------------------------------------------------------------------
      ln_gdp |      Coef.   Std. Err.      z    P>|z|     [95% Conf. Interval]
-------------+----------------------------------------------------------------
       ln_TA |   .1967149   .0091841    21.42   0.000     .1787144    .2147153
       _cons |   7.022355   .1610909    43.59   0.000     6.706623    7.338088
-------------+----------------------------------------------------------------
     sigma_u |   .9067813
     sigma_e |  .11739884
         rho |  .98351446   (fraction of variance due to u_i)
------------------------------------------------------------------------------
```

Hausman Test

```
. hausman fixed random

                 ---- Coefficients ----
             |      (b)          (B)            (b-B)     sqrt(diag(V_b-V_B))
             |     fixed        random       Difference          S.E.
-------------+----------------------------------------------------------------
       ln_TA |    .1950411     .1967149       -.0016738         .000703
------------------------------------------------------------------------------
                           b = consistent under Ho and Ha; obtained from xtreg
            B = inconsistent under Ha, efficient under Ho; obtained from xtreg

    Test:  Ho:  difference in coefficients not systematic

                  chi2(1) = (b-B)'[(V_b-V_B)^(-1)](b-B)
                          =        5.67
                Prob>chi2 =      0.0173
```

Appendix 4: GDP Impacts (US Millions, 2002 Prices)

<	**MML Impact**	**MPA Impact**	**CORAL Impact**	**END Impact**	**KBA Impact**
AFRICA					
Cape Verde	56.91	26.33	-218.92	426.46	274.93
Comoros	17.22	7.97	-66.26	129.08	83.22
Guinea-Bissau	16.28	7.54	-62.64	122.03	78.67
Mauritius	442.30	204.67	-1701.57	3314.68	2136.94
Sao Tome and Principe	0.00				
Seychelles	51.69	23.92	-198.85	387.37	249.73
TOTAL AFRICA	**584.41**	**270.43**	**-2248.25**	**4379.62**	**2823.49**
CARIBBEAN					
Antigua and Barbuda	75.58	34.98	-290.77	566.43	365.17
Aruba					
Bahamas, The					
Barbados					
Belize	86.09	39.84	-331.21	645.20	415.96
Cuba					
Dominica	23.11	10.69	-88.89	173.16	111.64
Dominican Republic	2611.34	1208.38	-10045.97	19569.68	12616.35
Grenada	36.01	16.66	-138.52	269.85	173.97
Guyana	61.03	28.24	-234.77	457.33	294.84
Haiti	276.75	128.06	-1064.67	2073.99	1337.08
Jamaica	738.54	341.76	-2841.22	5534.73	3568.18
Netherlands Antilles					
Puerto Rico					
St. Kitts and Nevis	32.95	15.25	-126.75	246.92	159.19
St. Lucia	61.35	28.39	-236.03	459.79	296.42
St. Vincent and the Grenadines	34.08	15.77	-131.12	255.42	164.67
Suriname	97.84	45.28	-376.41	733.26	472.72
Trinidad and Tobago	1069.01	494.68	-4112.54	8011.28	5164.78
Virgin Islands (U.S.)					
TOTAL CARIBBEAN	**5203.69**	**2407.98**	**-20018.89**	**38997.04**	**25140.95**
ASIA/PACIFIC					
American Samoa					
Northern Mariana Islands					
Fiji	133.31	61.69	-512.84	999.02	644.06
French Polynesia					0.00
Guam					0.00
Kiribati	5.77	2.67	-22.21	43.26	27.89
Maldives	75.49	34.93	-290.42	565.74	364.73
Marshall Islands	9.68	4.48	-37.23	72.52	46.75
Micronesia, Fed. Sts.	16.28	7.53	-62.61	121.97	78.63

Timor-Leste	26.14	12.10	-100.57	195.92	126.31
New Caledonia	0.00	0.00		0.00	0.00
Palau	9.65	4.47	-37.12	72.32	46.62
Papua New Guinea	321.85	148.94	-1238.19	2412.01	1554.99
Samoa	22.53	10.42	-86.66	168.81	108.83
Singapore	9809.65	4539.37	-37738.30	73514.66	47394.07
Solomon Islands	42.02	19.44	-161.65	314.90	203.01
Tonga	12.49	5.78	-48.06	93.62	60.36
Vanuatu	22.67	10.49	-87.22	169.90	109.53
TOTAL ASIA / PACIFIC	**10507.53**	**4862.31**	**-40423.07**	**78744.64**	**50765.78**

Appendix 5: Per Capita GDP Impacts, (USD, 2002 Prices)

	MML Impact	MPA Impact	CORAL Impact	END Impact	KBA Impact
AFRICA					
Cape Verde	114.11	52.81	-439.01	855.19	551.33
Comoros	26.76	12.38	-102.96	200.57	129.30
Guinea-Bissau	10.34	4.78	-39.76	77.46	49.94
Mauritius	348.59	161.31	-1341.03	2612.34	1684.15
Sao Tome and Principe					
Seychelles	594.43	275.07	-2286.82	4454.75	2871.93
TOTAL AFRICA	1094.23	506.35	-4209.58	8200.31	5286.65
CARIBBEAN					
Antigua and Barbuda	872.45	403.72	-3356.36	6538.22	4215.12
Aruba					
Bahamas, The					
Barbados					
Belize	267.29	123.69	-1028.29	2003.11	1291.38
Cuba					
Dominica	315.69	146.08	-1214.49	2365.83	1525.23
Dominican Republic	262.37	121.41	-1009.37	1966.27	1267.63
Grenada	347.77	160.93	-1337.90	2606.24	1680.22
Guyana	79.94	36.99	-307.51	599.04	386.20
Haiti	28.02	12.97	-107.80	209.99	135.38
Jamaica	274.84	127.18	-1057.32	2059.66	1327.84
Netherlands Antilles					
Puerto Rico					
St. Kitts and Nevis	669.82	309.96	-2576.84	5019.71	3236.15
St. Lucia	360.47	166.80	-1386.73	2701.37	1741.54
St. Vincent and the Grenadines	312.35	144.54	-1201.64	2340.82	1509.10
Suriname	189.94	87.90	-730.72	1423.46	917.69
Trinidad and Tobago	801.72	370.99	-3084.28	6008.21	3873.43
Virgin Islands (U.S.)					
TOTAL CARIBBEAN	4782.68	2213.16	-18399.24	35841.95	23106.90
ASIA/PACIFIC					
American Samoa					
Northern Mariana Islands					
Fiji	157.94	73.09	-607.60	1183.61	763.06
French Polynesia					
Guam					
Kiribati	59.79	27.67	-230.01	448.06	288.86
Maldives	247.49	114.53	-952.11	1854.72	1195.72
Marshall Islands	162.18	75.05	-623.93	1215.41	783.56
Micronesia, Fed. Sts.	147.40	68.21	-567.08	1104.67	712.17

Timor-Leste	23.80	11.01	-91.57	178.37	114.99
New Caledonia					
Palau	475.85	220.20	-1830.64	3566.10	2299.02
Papua New Guinea	48.94	22.65	-188.27	366.74	236.44
Samoa	125.94	58.28	-484.49	943.78	608.45
Singapore	2027.04	938.00	-7798.14	15190.86	9793.38
Solomon Islands	82.28	38.08	-316.54	616.63	397.53
Tonga	120.62	55.82	-464.04	903.95	582.77
Vanuatu	96.94	44.86	-372.93	726.48	468.35
TOTAL ASIA / PACIFIC	3776.22	1747.43	-14527.32	28299.40	18244.30

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