Journal of Environmental Management 271 (2020) 110968

Contents lists available at ScienceDirect

Journal of Environmental Management

journal homepage: http://www.elsevier.com/locate/jenvman

Research article

Market-driven bioeconomic general equilibrium impacts of tourism on resource-dependent local economies: A case from the western Philippines

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ARTICLE INFO

Keywords:
Tourism
Natural resources
Economic development
Bioeconomic models
CGE model

ABSTRACT

Tourism is frequently promoted as a strategy for sustainable economic development in developing countries. However, the preferred methodology for empirically assessing tourism's economic impacts on local economies, applied computable general equilibrium (CGE) modeling, does not account for how tourism affects local natural resource stocks upon which many households depend. We develop a bioeconomic local CGE model to show how market-driven impacts of tourism expansion affect natural resource availability over time. We then show how changes in resource availability affect local incomes of different socioeconomic groups. We parameterize our model with household, business, and tourist survey data from a municipality in the Philippines. We find that tourism expansion increases local real incomes in the short run, but this causes a decline in a local open-access natural resource that erodes real incomes over time, particularly for households engaged in the natural resource sector. Different market integration contexts, as expressed through trade linkages, can mitigate natural resource decline, but this reduces the overall local economic benefit of tourism.

1. Introduction

Tourism accounts for ten percent of global GDP and creates, directly or indirectly, one out of eleven jobs (UNWTO United Nations World Tourism Organization, 2015). It is one of the fastest growing sectors in developing countries. For example, in the Asia-Pacific region, tourism receipts tripled between 2004 and 2014 (UNWTO United Nations World Tourism Organization, 2015). Part of the allure of tourism is that it could achieve economic development while maintaining or even improving the environment (e.g., by providing livelihood alternatives to resource extraction) (Kiss, 2004; TIES The International Ecotourism Society, 2016; UNWTO United Nations World Tourism Organization, 2016). This potential has attracted considerable attention from governments and international agencies. The United Nations World Tourism Organization declared 2017 to be the "International Year of Sustainable Tourism for Development" (UNWTO United Nations World Tourism Organization, 2016).[1]

Despite widespread enthusiasm for using tourism as a tool for conservation and development, uncertainty about the interaction between these two goals remains (Kiss, 2004; Taylor et al., 2003, 2009; Agrawal and Redford, 2006). Tourism's value as a sustainable development tool depends on a complex set of linkages between tourism and economically important natural resources at tourist destinations. Studies have assessed the possibility that tourism may provide incentives for communities to protect natural amenities that attract tourists. However, results are mixed, given that many environmental goods are public goods or common-pool resources in places with weak institutional frameworks for resource management (Kiss, 2004). Tourism may also impact the environment directly, e.g., by damaging sensitive ecosystems like sand dunes and discharging sewage into water bodies (Kocasoy, 1995).

We examine how tourism affects natural resources through market-driven changes in local consumption and production patterns. When tourist expenditures enter a local economy, they ripple through markets

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[1] The term "ecotourist" is often used to describe tourists who are interested in nature, however in this paper we use the more general term because we are primarily interested in objective measures of tourist expenditures and how they influence local markets and consumption of natural resources.

https://doi.org/10.1016/j.jenvman.2020.110968
Received 9 January 2020; Received in revised form 12 June 2020; Accepted 12 June 2020
Available online 23 June 2020

for inputs, consumption goods, and factors of production and can have wide ranging impacts, including on natural resource sectors. We focus on market-driven impacts of tourist expenditures because they are likely to be large and because it is possible to measure expenditure flows directly with tourist surveys.

Market-driven impacts of tourism on resource extraction could be positive or negative. Alternative livelihoods in tourism activities may shift production away from resource extraction; however, it is also possible that increased local demand for resources from households and tourists increases natural resource extraction rates. A number of theoretical papers examine dynamic linkages among tourism, the environment, and economic development (e.g., Cerina, 2007; Giannoni and Maupertuis, 2007; Marsiglio, 2017; Ouattara et al., 2019). These approaches typically employ national-level models with a dynamic environmental resource stock, frequently deriving optimal policies such as the optimal level of tourist numbers, investment in tourist infrastructure, or tourism pollution abatement. They raise the possibility that market demand created by tourism may decrease environmental resources, and managing environmental consequences of tourism through policy actions like abating pollution could improve the long-run welfare of residents at tourist destinations. However, these frameworks are limited in that they do not empirically show tourism effects on economically important natural resources. In addition, they do not examine impacts at sub-national levels (the scale of most tourism hotspots) where, particularly in developing countries, there are often complicating factors such as market imperfections and producer-consumer households.

Applied computable general equilibrium (CGE) models are a preferred empirical methodology to assess the economic impacts of tourism, especially for local economies, because they (1) account for the complex linkages (e.g., labor markets, consumption good markets, and input markets) that determine how tourism dollars affect a local economy; (2) avoid the common challenge with tourism impact evaluation that there is no relevant control group for comparison; and (3) can be parameterized with locally-collected data (Winters et al., 2013; Taylor and Filipski, 2014; Banerjee and Cicowiez, 2015; Dwyer, 2015). Static applied CGE studies have shown that tourism expansion stimulates local economic activity, but that lower income groups often benefit less than higher income groups (Blake et al., 2008; Wattanakuljarus and Coxhead, 2008). Research focused on potential environmental impacts of tourism points to likely tradeoffs between growth in local incomes and the environment. Taylor et al. (2003) find that tourism in the Galapagos Islands increases household incomes, but it also stimulates production in natural resource sectors such as agriculture and fishing. They note that environmental impacts of tourism can be lessened by importing environmentally-sensitive goods from outside economies, but this shifts the economic benefits of tourism away from the local economy.

Static applied CGE models can empirically assess local economic impacts of tourism, but they do not explicitly account for how tourism affects local natural resources, how these environmental impacts persist over time, and the economic consequences for communities. For example, Taylor et al. (2003) show that tourism's stimulation of the local economy may increase production in the fishing sector, but they do not address how this would likely cause the local fish stock to decline over time. Because the availability of a natural resource affects the marginal productivity of labor in the resource sector, a declining resource stock would affect future profitability in the sector, harvesting effort, and local incomes. Impacts on natural resources are likely to have important welfare consequences, given that of the approximately one billion people living on less than a dollar a day, most live in rural areas and are dependent on natural resources for food, income, materials, or other needs (Millennium Ecosystem Assessment, 2005).

The contribution of this paper is to empirically assess how local economic consequences of tourism expansion change when one accounts for market-driven impacts of tourism on local natural resource stocks over time. This extends existing literature that examines tourism impacts using either static local applied CGE models or theoretical national-level dynamic models. We do this by linking an ex-ante impact evaluation tool from development economics (a local applied CGE model) with a dynamic model of a natural resource sector (a bioeconomic model). This modeling framework is similar to those of papers linking bioeconomic and CGE models for other purposes (Gilliland et al., 2019; Finnoff and Tschirhart, 2008; Seung et al., 2015; Gronau et al., 2018; Manning et al., 2018). We use this hybrid bioeconomic local CGE model to simulate how an exogenous increase in tourism expenditures affects natural resource availability and real incomes of different socioeconomic groups over time. Agrawal and Redford (2006) highlight the need to assess how the impacts of tourism vary based on local economic context. To address this, we examine different trade scenarios that vary based on the degree to which imported goods are substitutable for the locally-harvested natural resource. We apply our bioeconomic local CGE model to a rural municipality in the western Philippines (El Nido) whose economy is dominated by tourism and fishing. We parameterize the model with a unique data set from household, business, and tourist surveys conducted at the field site in 2015.

We find that rather than shifting economic activity to non-resource sectors, tourism expansion increases natural resource extraction, and this affects future economic outcomes for all socioeconomic groups. However, impacts vary by household group and trade scenario. When imports are less substitutable with local natural resources, local demand for the resource stimulates harvesting pressure and a decline in the local resource stock. Initial real income gains experienced by all households decline or are eliminated over time, particularly for resource-dependent households. This suggests that if trade in a natural resource is limited, an applied CGE model without the bioeconomic component would tend to overestimate the benefits of tourism to households by failing to account for potential declines in natural resource stocks. If imports are near perfect substitutes for the local natural resource, an increase in tourism reduces fishing pressure moderately by stimulating growth in non-resource sectors and imports of natural resources. Nevertheless, overall local economic stimulation is lower, because importing goods results in a smaller local production response.

The next section describes the core features of the bioeconomic local CGE model, the field site, data set, and estimation of model parameters. Section 3 presents the results of a simulated exogenous increase in tourism expenditures on a local economy and its natural resource base under different trade scenarios, along with several sensitivity analyses. Section 4 concludes.

2. Methods

2.1. Linking a local CGE model and bioeconomic model

Our bioeconomic local computable general equilibrium model is based on the modeling framework found in Taylor and Filipski (2014) and similar to Gilliland et al. (2019). Related frameworks have recently been used to examine the issues of aquaculture (Gronau et al., 2018) and fisheries management (Manning et al., 2018) in developing country contexts. In the model, household production technologies for all goods take the Cobb-Douglas form with constant returns to scale, but for natural resource harvesting, production is also a function of the resource stock size. Thus, a household-specific value added production function is given by

$$QP_{h,t} vash_h = A \prod_f FD_{h,f,t}^{\beta_f} X_t^{\beta_{stock}} \tag{1}$$

where $QP_{h,t}$ is quantity produced at time period t by household h, $FD_{h,f,t}$ are factor demands, $vash_h$ is the value added share, and X_t is the resource stock size. The parameter A represents a shift parameter, and the β parameters represent output elasticities. Each time step is one year in the model. We model the natural resource as an open-access setting. Since it is not known how the value added attributable to the stock gets divided among the remaining factors, as in Manning et al. (2018) we assume each factor f collects a share of the value added attributable to the stock, denoted θ_f. The share collected derives from a factor's contribution to value added so that $\theta_f = \frac{\beta_f}{\sum_f \beta_f}$. Thus, the first order conditions for factor demands for resource harvesting can be written

$$FD_{h,f,t} = \frac{QP_{h,t}PVA_{h,t}(\beta_f + \theta_f \beta_{stock})}{W_{h,f,t}} \quad (2)$$

where $FD_{h,f,t}$ is demand for factor f, $PVA_{h,t}$ is the price value added for the resource, and $W_{h,f,t}$ is the wage for factor f. This specification accounts for the over-allocation of factors to resource harvesting due to open-access and ensures that effort is allocated to harvesting until the resource rent is driven to zero. We model intermediate input demands as Leontief (constant input-output ratios).

Household incomes in the CGE model are the sum of payments to factors owned by the household plus exogenous forms of income such as remittances. Consumption demands are derived from constant elasticity of substitution utility functions. As in Taylor et al. (2003), we assume that the amount of tourist expenditures entering the economy is exogenous to changes in the local economy. We also derive tourist demands from a constant elasticity of substitution utility function.

For goods that are imported and produced in the local economy, imports and locally produced goods are combined into a composite good using an Armington function, which allows for imperfect substitutability between imports and local goods (Armington, 1969). The composite good is an input for production activities and is consumed by households.

We assume that the system is in steady state in the baseline, but the resource stock changes over time in response to tourism-induced changes in harvesting pressure, altering productivity in future periods. To account for this, we link the local CGE model described above with a dynamic resource stock model. For simplicity, we assume logistic growth, with the intrinsic growth rate and carrying capacity denoted by γ and K, respectively. The population dynamics for the stock take the following form

$$X_{t+1} = X_t + \gamma X_t\left(1 - \frac{X_t}{K}\right) - \tau\sum_h QP_{h,t} \quad (3)$$

where X_t is the stock level at time t and τ translates the units of output into kilograms. Within a given time period, the model solves for equilibrium prices and quantities in the economy conditional on a fixed resource stock level for that year, X_t. The resource stock is then updated in the next time period according to Equation (3), and the new stock size affects the local economy via linkages in factor and goods markets. We assume that as the stock size diminishes, input costs (e.g., petrol) go up due to increasing search costs when there are lower levels of the resource, as outlined in Gilliland et al. (2019). A full presentation of model equations is presented in the Supplementary Materials (Tables A1-A5).[2]

The abiotic environment is also an important factor that influences the biotic environment, and it may be affected by tourism. Adequate data on abiotic dimensions of the local landscape were not available but could be relevant (e.g., increased siltation damage to coral reefs resulting from expanding tourism development). In other studies where data were available, abiotic components of ecosystems were found to have impacts on the optimal economic management of food systems (e.g., Johnson and Martinez, 2000; Berazneva et al., 2019), suggesting future research should incorporate these factors when data become available.

[2] The bioeconomic local CGE model described above is programed using General Algebraic Modeling System (GAMS); the GAMS code and data input sheet are available upon request.

2.2. The field site, El Nido, Palawan, the Philippines

We apply our model to the municipality of El Nido on the island of Palawan in the western Philippines (2015 population, 36,000; Fig. 1). El Nido is an appropriate location to examine how tourism affects local incomes and natural resource use because, as with many other tourism hotspots, its population is dependent on both tourism and local natural resources. Tourism-related activities constitute the largest contribution to GDP in the local economy, with hotels and restaurants contributing 35 percent and tours contributing 15 percent. Retail stores where households buy food and businesses purchase inputs also contribute a large fraction of GDP (23 percent). Other services contribute 12 percent of GDP. Fishing (9 percent) and farming (7 percent) account for smaller shares, but they are common activities for poor households. In addition, fish are the primary source of animal protein in the Philippines with average annual per capita fish consumption of 32.7 kg (FAO Food and Agricultural Organization, 2014).

Tourism in El Nido is growing rapidly and regional tourism development plans for Palawan and surrounding areas include a focus on using tourism as a tool for sustainable development in the region (Tomeldan, 2009). On a national scale, the Philippine government is promoting tourism as a livelihood alternative to fishing, in an effort to combat overfishing in artisanal fisheries (Fabinyi, 2010).

El Nido's near-shore fishery is open access and suffers from overfishing. Large commercial vessels are not permitted within 15 km of shore, but for the large number of small-scale fishers, there are no restrictions on the number of fishing days or the number of boats, and registering one's fishing boat is free. The El Nido-Taytay region has a designation as an IUCN category VI protected area, however this designation allows people to live in the area and use natural resources, and the area still struggles with substantial overfishing by small-scale fishers. There are some local gear restrictions (such as net gauge); however with the exception of cyanide and bombs, enforcement of regulations is limited. The most common gear-types used in El Nido are bottom-set gillnet and hook-and-line, though some households also use driftnets and spearfish. Tunas, mackerels, groupers, and squid are the most often caught species by weight.

2.3. Survey data, model parameterization, and model constraints

We implemented surveys of households, businesses, and tourists in 2015. The 464 household surveys (6.2% of households) gathered data on family member time use, household assets, income, and household expenditures. A total of 282 business surveys collected information on usage of labor and capital, inputs expenditures, and output. The tourist surveys collected data on tourist expenditures and where these expenditures were made. Detailed information about survey methodology can be found in Gilliland et al. (2019).

Using the survey data, we created four representative household groups in the model based on whether households were above or below the poverty line (nonpoor/poor) and whether the households engaged in fishing (fishing/nonfishing).[3] Summary statistics for these household groups are found in Table 1. In our household surveys, we defined households as groups of people who live together and normally share their meals, not including anyone who has been away for six months or more. Nonresidents who own local businesses, primarily in the hotel sector, constitute an additional household group in the model. They do

[3] We use the Philippine Government's 2015 per capita poverty line (427USD per year) for Palawan. Income was approximated using expenditure data given that in developing-world contexts consumption data are thought to be more reliable for capturing long-run welfare levels than current income (Gillis et al., 2001).

Fig. 1. Panel A: El Nido is located on the northern tip of the island of Palawan in the western Philippines. Panel B: The tourist waterfront with hotels and restaurants. Panel C: Small-scale fishers fishing the nearshore waters.

Table 1
Summary statistics for households surveyed in El Nido.

Household group (n)	Average consumption expenditures (USD)[a]	Percent sometimes concerned about having enough food	Average household size	Average adult education level (years)
Fishing nonpoor (87)	779.7 (328.73)	2.3	4.8 (1.88)	6.8 (4.44)
Fishing poor (50)	323.3 (69.36)	10.0	5.9 (2.23)	5.7 (4.00)
Nonfishing nonpoor (221)	954.7 (577.21)	3.6	4.6 (2.03)	8.8 (4.95)
Nonfishing poor (106)	290.5 (88.28)	9.4	5.3 (2.26)	6.9 (4.61)

Note: Standard deviations are in parenthesis.
[a] The official provincial poverty line is 432.7USD.

not live in El Nido and therefore have no local consumption expenditures.

Survey data on local production activities were used to designate the six primary production activities: Tourism activities, fishing, hotels, retail, agriculture, and other services. We combine fishery products into an aggregate good because fishers target many species at the same time using multiple gears, including ones that are unselective such as gillnets. The household groups are heterogeneous with respect to production activities (Supplementary Materials Table A6). Fishing households primarily engage in fishing and agricultural activities; nonpoor fishing households employ relatively more capital in both of these activities. Poor nonfishing households primarily engage in agriculture and retail. Nonpoor nonfishing households are responsible for a significant amount of the production in all nonfishing activities of the economy, including tourism. Nonresidents are primarily active in tourism-related sectors.

We econometrically estimate parameters in our model using our survey data, similar to other recent works employing local CGE models; this differs from the traditional method of using a social accounting matrix to calculate aggregate shares (Taylor and Filipski, 2014). Demand parameters are estimated for each household group, but for the estimation of production parameters we pooled observations because data from business surveys were not linked to household groups. This implies that production technologies for each production category are the same across households. The estimated household expenditure shares and output elasticities for production are in Supplementary Materials Table A7 and A8.

Tourists reported disaggregated expenditure data (53 percent of tourists) or aggregate fees from tour packages, which included lodging, boat tours, and transportation. For the latter, we arranged interviews with companies selling tour packages to estimate the fraction spent on various goods. These data were used to derive the share parameters in the tourist CES utility function. The largest fraction of tourist expenditures went to lodging and restaurants (69 percent). Among other good categories, tourists spent 22 percent of their expenditures on tourism activities like beach visits, renting bikes, snorkeling, and diving; 8 percent on other services; and 1 percent on miscellaneous retail items.

We use values from the literature for parameters that we are not able to estimate from survey data. Tourism activities (e.g., boat trips), hotel stays, spending at local retail stores, and other services are non-tradable goods because they are inherently produced locally, however fish and agricultural goods are imported into the El Nido economy. Field surveys revealed that imports supplied 11 percent of fish and 13 percent of agricultural consumption in El Nido. The distinction between tradables and nontradables can be subtle and complex. For example, most of the merchandise sold in retail shops is purchased outside the local economy at a fixed price, but the shop may also purchase nontradable goods and factors, the prices of which may change in our simulations; thus, the value-added portion of retail prices is nontradable. Our model captures these nuances within production activities.

Choosing the Armington elasticities for goods that are imported from surrounding areas and produced locally within the municipality is challenging because the model is at the scale of a municipality. In the literature, estimates are frequently for countries or regions. At the country level, locally produced goods and goods imported from other countries are likely less substitutable. For example, fish imported from other countries are more likely to be of different species than those caught within the country, and they may vary in terms of processing (e.g., frozen versus fresh). However, traders we interviewed reported importing primarily the same species (caught in a large, nearby fish-producing region south of El Nido) that were fresh, not frozen. The substitutability between imported and locally produced agricultural goods is likely to be similar to that of fish. The staple crop in El Nido is rice, and the rice imported into El Nido comes from large rice producing areas on the same island. As a result, we use Armington elasticities that are higher than those reported in the literature from country-scale models. This assumption is supported by empirical findings that goods do not flow as easily across country borders as they do across local and state boarders (Anderson and van Wincoop, 2003). However, the challenge of keeping foods fresh likely results in a lack of perfect substitutability in this context due to issues with transportation infrastructure (unpaved roads) and low quality ice for preservation. Reported values at the country level for agricultural goods range from 1.03 to 6, and for fish estimates range from 0.82 to 2.8 (Hertel, 1997; Annabi et al., 2006). We set the Armington elasticities at a value of 8 for both of these good types and, given uncertainty about parameter values, examine a range of different elasticities to explore how simulation results change under different elasticity values. This provides an opportunity to examine how localities with different local trade scenarios may vary in how they are affected by tourism expansion. CES utility functions allow households to substitute away from food items that become more expensive. We assume the poor will readily switch food sources so we use a high elasticity value of 3. Tourists are mostly buying non-essential items, so their elasticity of substitution in consumption is also set at a value of 3.

In the biological system, the initial stock size is set at 36 percent of carrying capacity, based on preliminary ecological surveys from the El Nido region (Alice Rogers, personal communication, 2016) and fisheries literature reporting that nearshore fish stocks with similar species in developing countries tend to be characterized by high levels of exploitation and greatly reduced biomass (Worm et al., 2009; Kellner et al., 2011). The intrinsic growth rate for an aggregate fish stock cannot be estimated directly; we use and intermediate fish population growth rate of 0.50 (Manning et al., 2018).

We assume no migration; that is, the number of households is fixed. There is significant unemployment (14 percent) and underemployment in this area (PEP CBMS Partnership for Economic Policy Community Based Monitoring Survey, 2011). As in Filipski et al. (2015), we start by assuming that the labor supply is nearly perfectly elastic to reflect high unemployment rates and conduct a sensitivity analysis on the elasticity of labor supply.

The factors of production in the economy include hired labor, family labor, capital, purchased factors such as fertilizer, and land.[4] We assume fixed capital in each economic activity, a common assumption in micro agricultural-household and GE modeling. This effectively restricts our analysis to a relatively short time interval (ten years). We leave modeling households' endogenous choice of capital investment or divestment in production activities for future research, acknowledging that it would provide a more realistic model of how households respond to shocks in the tourism sector. Arable land in El Nido is relatively scarce due to steep terrain, so the amount of land in agriculture is considered fixed.

3. Results

We use the bioeconomic local CGE framework to simulate the impact of an increase in tourism expenditures on the local economy and natural resource stock (fish population) in El Nido. Starting from a bioeconomic equilibrium where initial harvest (measured from survey data) equals growth in the fish stock, the simulation increases the total level of exogenous tourism expenditures by 10 percent. This is roughly equivalent to the annual level of increase in tourism at our field site and similar to what is used in other assessments of the impacts of tourism expansion (e.g., Taylor et al., 2003). The model holds tourist expenditures constant at this level for 10 years to examine impacts on the dynamic natural resource stock over time. We present results for the base parameter values described above, examine the influence of trade context, and perform sensitivity analyses to illustrate the robustness of our results.

3.1. Results for base parameter values

Table 2 reports the impact of the 10 percent increase in tourism expenditures on fish biomass and local economic outcomes. The column labeled "base values" contains the model results for the base parameters outlined in Section 2.3. The local economic impacts in year 1 are the results one would obtain using a CGE model without the bioeconomic component. In following years, changes in the natural resource level ripple through the local economy, reflected in the column for year 10.

The increase in tourism expenditures initially has a positive impact on all household incomes. The largest gains in real income among resident households accrue to the nonpoor nonfishing households because they own the highest level of capital in tourism-related sectors. Nonresidents, who own capital primarily in the hotel sector, reap large real income gains from tourist spending in their establishments. The poor nonfishing households also experience appreciable gains in real income (relative to their base income), because this group owns capital in the retail sector and participates actively in the market for hired labor. Fishing households benefit from higher demand for fish initially; however, their gains are relatively small because they do not own capital in tourism-related sectors and they primarily produce tradable goods.

The increase in tourism expenditures results in more demand for fish. This is due to higher demand for fish as an input (e.g., at tourist restaurants) and from households whose incomes have increased. This raises the demand for fish imports and locally produced fish. The latter puts upward pressure on the local price of fish, resulting in higher fish harvest, which causes a decline in the fish stock over time. The bold black line in Fig. 2 plots the decline in the fish stock over the 10-year period.

All household incomes are negatively impacted by the decline in the fish population over time (Table 2 and Panel C on Fig. 3), *ceteris paribus*. Fishing households, which are net sellers of fish, suffer disproportionately. By the tenth year of the simulation, both nonpoor and poor fishing households earn real incomes below their baseline levels. Nonfishing households are also negatively affected by the fish stock decline, but the impact on nonfishing households is smaller because they are affected indirectly through prices and diminished spending by fishing households. Nonresidents feel some limited impact of the fish population decline, due to diminished local spending at their businesses and higher input costs for fish, but this impact is small because nonresidents do not make consumption purchases locally.

In Table 3 we provide the dollar value of the tourism shock, calculated as the difference in the per capita present value of a household's real income stream over the 10 years with and without the tourism shock. To highlight the value of including the bioeconomic model, we give results from the hybrid bioeconomic CGE model (Column B) and for a simple CGE model that assumes a constant resource stock size (Column S). The columns labeled Δ contains the difference between results from the bioeconomic vs. simple model (Δ = B–S). We use a discount rate of 0.05.

The present values of the tourism shock using a local CGE model without the bioeconomic model (Column S in Table 3) are largely consistent with findings from other tourism impact evaluation studies. All resident households benefit from the increase in tourism, and it is the richest household group (nonpoor nonfishing households) that benefits most (Taylor et al., 2003; Blake et al., 2008; Wattanakuljarus and Coxhead, 2008). Among nonpoor households, nonfishing households that

[4] F-tests reject the null hypothesis that family labor and hired labor have the same productivity in three out of the six sectors (fishing, agriculture and retail), which formed the basis of our decision to separate family and hired labor in the model, which is similar to other local CGE models of rural economies in developing countries (e.g., Filipski et al., 2015; Manning et al., 2018).

Table 2
Impacts of an exogenous 10 percent increase in tourism expenditures on fish biomass (percent of carrying capacity (K)) and economic variables (percent change from baseline) for different Armington elasticities for agricultural goods and fish.

Armington Elasticities	200		20		8 (base value)		2	
	Year		Year		Year		Year	
	1	10	1	10	1	10	1	10
Fish biomass (% of K)	36.0	36.2	36.0	34.2	36.0	31.9	36.0	28.0
Real income								
Fishing nonpoor	0.1	0.4	1.9	−0.5	3.2	−1.5	4.9	−2.8
Fishing poor	−0.5	−0.1	1.5	−1.4	3.1	−2.7	5.0	−4.6
Nonfishing nonpoor	12.7	12.8	13.7	13.2	14.5	13.5	15.5	14.1
Nonfishing poor	10.9	11.0	12.2	11.5	13.3	12.0	14.7	12.9
Nonresident	15.6	15.6	15.3	15.3	15.1	15.0	14.8	14.3
Prices								
Agricultural goods	0.3	0.3	2.8	2.7	5.0	4.8	7.9	7.8
Fish	0.3	0.3	2.0	2.8	3.4	6.4	5.0	15.4
Hotels/re staurants	4.4	4.4	4.6	4.6	4.8	4.8	5.0	5.2
Retail goods	2.5	2.5	3.0	2.9	3.4	3.4	3.8	4.5
Other services	4.8	4.8	5.5	5.2	6.0	5.7	6.7	6.8
Tourism activities	5.6	5.6	5.7	5.7	5.9	5.8	6.0	6.1
Aggregate production								
Agricultural goods	0.0	0.0	1.2	1.2	2.2	2.1	3.6	3.5
Fish	−0.4	0.2	2.8	−1.5	5.3	−3.1	8.1	−5.2
Hotels/restaurants	5.8	5.8	5.7	5.7	5.6	5.5	5.5	5.2
Retail goods	7.0	7.1	8.0	7.7	8.9	8.4	10.0	10.0
Other services	3.8	3.9	4.2	4.0	4.6	4.2	5.0	4.7
Tourism activities	2.4	2.4	2.4	2.4	2.4	2.4	2.4	2.4
Imports								
Agricultural goods	99.7	100.7	75.4	71.5	51.5	48.1	20.5	20.4
Fish	75.3	72.6	54.1	69.6	37.8	59.5	19.2	26.2
Nominal GDP	10.6	10.7	11.9	11.1	12.9	11.5	14.3	12.5

Note: Results are presented for year 1 and year 10 of the simulation. Results in year 1 represent the impact of the tourism shock on the local economy prior to any changes in the fish stock size (i.e., the results without a dynamic bioeconomic component to the model). Fish biomass is at 36 percent of carrying capacity (K) in the baseline.

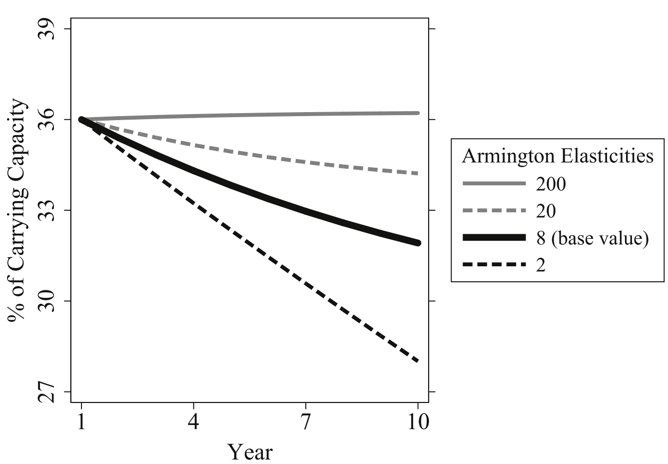

Fig. 2. Change in fish stock size as a result of the exogenous 10 percent increase in tourism expenditures. In the baseline (prior to the increase in tourism expenditures), the stock is at 36% of carrying capacity.

own more capital in tourism-related sectors benefit most, and among poor households, fishing households that almost exclusively produce tradable commodities (fish and agricultural goods) benefit least.

The results from the bioeconomic model (Column B) illustrate how failing to account for impacts on natural resources results in biased estimates of tourism's benefits. Every household has a lower per capita present value benefit once we account for the fish stock decline. The loss is most severe among fishing households, which depend directly on the fish resource. Nonpoor fishing households' per capita present value gain from the shock declines from $200 to $58, whereas the gain to poor fishing households is nearly eliminated, falling from $80 to $7. The impact on nonfishing households is also negative, but it is small because their economic links to the natural resource are less direct. The benefits to nonpoor nonfishing households decline from $1050 to $1016, while benefits to poor nonfishing households decline from $309 to $294. Note that these results depend on the discount rate and the period of time considered. Lower discount rates and a longer timeframe would weigh the negative effects of the fish stock decline more heavily because the decline takes place in future periods.

3.2. Examining trade

Given that trade can mediate the impacts of local economic shocks (Donaldson, 2010), we examine how tourism's impacts vary depending on local trade context. In the model, the trade context is expressed through the degree to which imports of tradeable goods (fish and agricultural products) are substitutable for their locally produced counterparts, which likely would vary based on factors such as transportation infrastructure or variation in the variety of goods produced in neighboring regions. In the model, this is governed by Armington elasticities (Supplementary Materials Tables A1-A5); a high (low) Armington elasticity of substitution implies that households and businesses are more (less) willing to substitute imports for locally produced goods when local prices rise.

When imports are less substitutable for locally produced tradable goods (i.e., low Armington elasticities for fish and agricultural goods), there is a lower demand for imports, a higher demand for locally produced goods, higher local prices, and increased initial output of locally produced goods (Table 2). In the case of fish, this results in higher harvesting pressure for fish and a larger decline in the fish population (Fig. 2). Thus, if close substitutes cannot be imported, tourism may have a larger negative impact on local natural resource stocks.

Alternatively, high Armington elasticities buffer local prices of tradable goods from the tourism shock. If imported fish are a near perfect substitute for locally caught fish (i.e., large Armington elasticities), imports rise sharply, which keeps the local price of fish low relative to

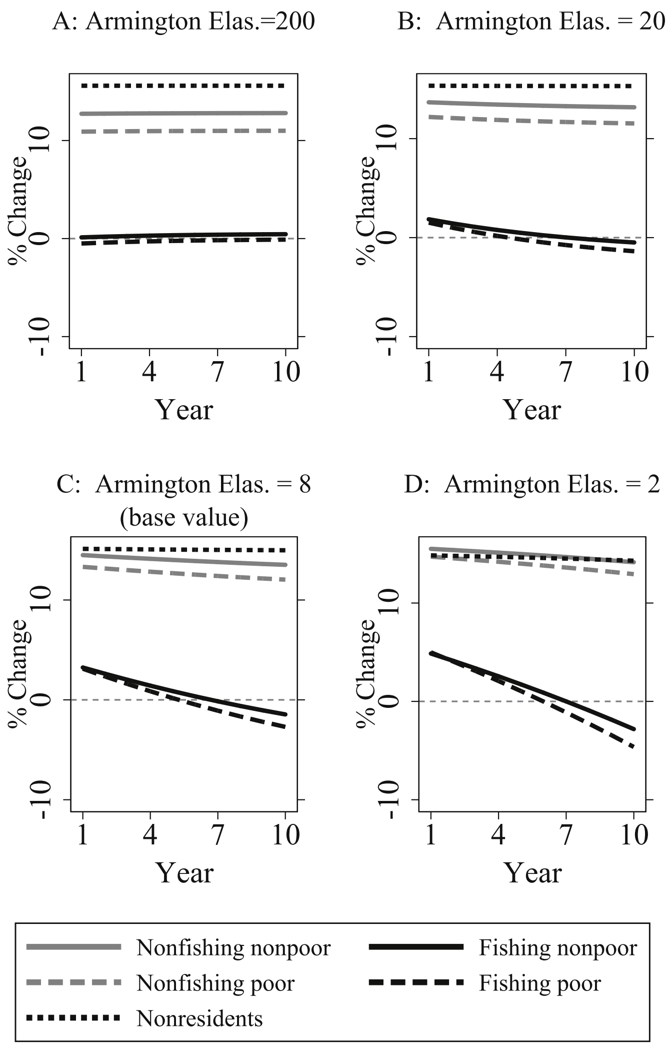

Fig. 3. Percent changes in real incomes for household groups and nonresidents as a result of the exogenous 10 percent increase in tourism expenditures. These changes are relative to baseline real income levels and are shown for four different values of the Armington elasticities of substitution for agricultural goods and fish. Panel C represents the base values for these Armington elasticities.

nontradable goods in the economy. This makes fishing relatively less profitable than nontradables production and causes a small decline in local fish production, which in turn results in a small increase in the fish stock over time (Fig. 2). Thus, if a local economy has access to perfect substitutes for locally produced fish, tourism could diminish pressure on local fish stocks by increasing imports of fish and shifting local production effort to other sectors such as tourism.

The substitutability between imported and locally produced fish and food has implications for households' real incomes. When imports and locally produced goods are less substitutable, there is a greater local production response, and this results in higher benefits for resident households overall (Fig. 3 and Table 3). Nonresidents are slightly worse off because they only own businesses that target tourists (not local residents). These businesses generally do not benefit from increased household spending, and they face higher input costs with greater stimulation of the local economy.

In contrast, as imports become more substitutable with locally produced goods, there is a smaller local production response, and real incomes of resident households decrease (Table 3). As noted in Taylor et al. (2003), this signals an important tradeoff vis-à-vis trade. Greater access to trade in natural resource products may relieve pressure on natural resources associated with tourism expansion. However, greater reliance on imports reduces local production responses, diminishing income gains targeted by those who promote tourism as a way to improve local economies. Over the 10-year period we consider, households are worse off when there are higher levels of trade and less pressure on the local fish stock (Table 3). However, an important caveat is that the negative consequences of the fish stock decline are in the future, so these results could change with a different discount rate or time horizon.

3.3. Sensitivity analyses

For some model parameters, few if any reliable estimates exist for local economies in developing countries due to a lack of experimental or matched panel data and resource stock estimates that can support econometric estimation. For these parameters, sensitivity analyses illustrate the robustness of model results to changes in parameter values.

The qualitative impacts of tourism are robust to different values of the elasticity of substitution in consumption, and observed changes in magnitude are small (Table 4). When the elasticity of substitution in consumption is larger, households substitute away from fish more

Table 4
Sensitivity analysis for the elasticity of substitution in consumption.

Elasticity of substitution in consumption	4		3 (base value)		2	
	Year		Year		Year	
	1	10	1	10	1	10
Fish biomass (% of K)	36.0	32.1	36.0	31.9	36.0	31.7
Real income						
Fishing nonpoor	3.3	−1.4	3.2	−1.5	3.2	−1.5
Fishing poor	3.2	−2.6	3.1	−2.7	3.0	−2.8
Nonfishing nonpoor	14.0	13.2	14.5	13.5	15.2	14.0
Nonfishing poor	13.0	11.8	13.3	12.0	13.8	12.3
Nonresident	15.1	15.0	15.1	15.0	15.0	14.9

Table 3
Present value of the tourism shock in US dollars using the full bioeconomic CGE model (B), a simple CGE model without a bioeconomic component (S), and the discrepancy between the two (Δ=B–S).

Armington Elasticity	200			20			8 (base value)			2		
Model	B	S	Δ	B	S	Δ	B	S	Δ	B	S	Δ
Fishing nonpoor	19	8	11	37	115	−78	58	200	−142	95	301	−206
Fishing poor	−7	−13	6	−1	39	−40	7	80	−73	21	128	−107
Nonfishing nonpoor	925	922	3	971	990	−19	1016	1050	−34	1082	1123	−41
Nonfishing poor	254	253	1	274	283	−9	294	309	−15	323	341	−18

Note: This table presents the change in the present value of household per capita income for the ten year period under different assumptions about the Armington trade elasticities. Model (S) is identical to model (B) except that it assumes the fish stock is fixed. The Δ column can be interpreted as the change we expect in the present value as a result of including a bioeconomic model. Nonresident households could not be surveyed so it was not possible to calculate per capita income figures for this group. The discount rate used is 0.05.

Table 5
Sensitivity analysis for labor supply elasticity.

Labor supply elasticities	100 (base value)		10		5	
	Year		Year		Year	
	1	10	1	10	1	10
Fish biomass (% of K)	36.0	31.9	36.0	32.2	36.0	32.6
Real income						
Fishing nonpoor	3.2	−1.5	2.9	−1.2	2.6	−0.9
Fishing poor	3.1	−2.7	2.7	−2.3	2.4	−2.0
Nonfishing nonpoor	14.5	13.5	14.5	13.7	14.5	13.8
Nonfishing poor	13.3	12.0	13.3	12.2	13.3	12.4
Nonresident	15.1	15.0	15.3	15.2	15.5	15.3

readily as the price of fish increases, resulting in a more moderate fish stock decline.

Due to high levels of unemployment in El Nido, our base model assumes a high labor supply elasticity. Model results do not change substantively for values of the labor supply elasticity that remain relatively elastic (Table 5). For a less elastic labor supply, sectors stimulated by tourism must compete for a limited labor supply, wages rise, and there is a smaller decline in the fish stock when tourism stimulates the local economy. In general, the real incomes of households do not change substantively. We do not see large deviations from these results unless labor is scarce, but this is unlikely to be the case in El Nido given high unemployment.

In bioeconomic models, the fish intrinsic growth rate parameter affects the dynamic responsiveness of the fish stock to changes in harvest. Our model assumes that the bioeconomic system is at steady state in the baseline, which requires that fish growth equals harvest in the baseline economy. The intrinsic growth rate and initial stock's fraction of carrying capacity are used to calibrate the unknown initial stock size such that baseline growth in fish biomass is equal to baseline harvest. Therefore, examining model results for different growth rate values implies also calibrating a new initial stock size. For example, when the intrinsic growth rate is higher, this implies a lower calibrated initial stock size to ensure that fish growth is still equal to baseline harvest. We assess model results for different combinations of growth rate and initial stock size (Table 6). The general results of the increase in tourism expenditures on the El Nido economy are not sensitive to changes in the fish growth rate. When there is a higher fish growth rate and lower calibrated initial stock size, an equal-sized tourism shock results in a bigger percentage decline in the stock, which causes larger declines in real incomes, particularly for fishing households. The decline in stock is larger in percentage terms because the calibrated initial stock size is smaller. However, the actual stock decline in biomass is smaller for higher intrinsic growth rates because the stock grows more quickly.

Table 6
Sensitivity analysis for the intrinsic growth rate parameter.

Intrinsic growth rate	0.6		0.5 (base value)		0.4	
	Year		Year		Year	
	1	10	1	10	1	10
Fish biomass (% of K)	36.0	31.4	36.0	31.9	36.0	32.5
Fish biomass (millions kg)	4.31	3.75	5.18	4.59	6.47	5.85
Real income						
Fishing nonpoor	3.2	−2.2	3.2	−1.5	3.2	−0.7
Fishing poor	3.1	−3.6	3.1	−2.7	3.1	−1.7
Non fishing nonpoor	14.5	13.4	14.5	13.5	14.5	13.7
Non fishing poor	13.3	11.8	13.3	12.0	13.3	12.3
Nonresident	15.1	15.0	15.1	15.0	15.1	15.0

Note: The initial stock size is calibrated and therefore is not constant when varying the intrinsic growth rate. In the above table, the stock size is provided in kilograms of biomass for comparison. See text for additional details.

4. Conclusions

Our results about the initial impacts of tourism on a local economy and household incomes are largely consistent with static applied CGE models of tourism impacts in developing country contexts (e.g., Taylor et al., 2003; Blake et al., 2008; Wattanakuljarus and Coxhead, 2008). We extend the literature by showing how impacts of tourism change over time if one accounts for market-driven impacts of tourism on natural resource stocks exploited by local households. We do this by linking an applied local CGE model to a bioeconomic model of natural resource harvesting. If trade in the natural resource is limited, we find that tourism expansion increases local real incomes in the short run, but this causes a decline in local natural resources that erodes incomes over time, particularly for households engaged in the natural resource sector. An applied CGE model without a bioeconomic component overstates the benefits of tourism for local households by failing to account for the decline in the resource stock. If imports are near perfect substitutes for the local natural resource, an increase in tourism reduces harvesting pressure moderately by stimulating growth in non-resource sectors and resource imports, but initial local economic stimulation is lower because importing goods results in a smaller local production response. This is consistent with theoretical findings that access to trade may decrease pressure on an unmanaged local natural resource when the local economy imports the natural resource (Brander and Taylor, 1997). However, imports transfer harvesting pressure to other (resource-exporting) regions, creating an imperative to manage natural resources in those areas.

Our analysis focuses on market-driven impacts of tourists on the local economy and natural resource levels because they are likely to be large in relative magnitude, and it is possible to measure expenditure flows directly with tourist surveys. The linkages between tourists, the environment, and the local economy are potentially more complex than this. Tourist demand for natural amenities may incentivize conservation, such as can be the case with community based tourism and ecotourism endeavors (Kiss, 2004; Agrawal and Redford, 2006), and tourists may purchase recreational fishing trips (e.g., Sarr et al., 2008). Tourists' use of ecosystems can also damage the environment (e.g., air pollution and waste water) (Kocasoy, 1995). These factors could lead to environmental impacts that are smaller or larger than what we find. It is also possible that reductions in environmental quality at the tourism site could decrease tourism demand (Cerina, 2007). For example, Avila-Foucat and Eugenio-Martin (2008) show that hypothetical changes in the number of charismatic species like crocodiles could impact a tourist's tendency to revisit the same tourist site. As noted by Ouattara et al. (2019), empirical estimates of a reciprocal relationship between tourist expenditures and environmental quality over time are not available. Expanded empirical bioeconomic general equilibrium modeling frameworks that consider more complex interactions between tourism and the environment in developing countries are needed.

Fixed capital stocks are a common assumption in micro agricultural-household and CGE modeling. Modeling endogenous choice of capital is particularly challenging in this context given the lack of data on capital markets and the possibility that these markets are not well-functioning. In addition, modeling capital choice in a dynamic context requires an optimal control theory modeling framework to determine the optimal policy function for fishing capital, which is beyond the scope of this paper. Nonetheless, allowing households the ability to choose capital levels would likely mediate the impacts of tourism on the natural resource stock in several ways. The increased demand for fish resulting from the increase in tourism expenditures would likely spur capital investment in the fishing sector, leading to greater capacity in the sector and steeper initial declines in the fish stock. However, as the fish stock declines, this would lead to a decline in the marginal returns to capital in the fishery, likely leading households to shift capital to alternative income generating opportunities. This latter effect could moderate the fish stock decline and help households smooth income losses resulting from the resource decline. Future studies should incorporate these dynamics into modeling frameworks as appropriate data become available.

Our findings have potential implications for reforming common pool resource management in developing countries. Fisheries management has the potential to greatly increase the amount of wealth created by small-scale fisheries (Arnason et al., 2009; Wilen, 2013), and various interventions have been designed and implemented (Jardine and Sanchirico, 2012). The resource at our study site, as at many tourist destinations in developing counties, is open-access. Because of this, rents from fishing are dissipated. Complementing tourism expansion with natural resource management institutions capable of generating rents could increase the local economic benefits of tourism while shifting the distribution of benefits across socioeconomic groups.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Ted E. Gilliland: Conceptualization, Data curation, Formal analysis, Investigation, Methodology, Project administration, Software, Supervision, Writing - original draft, Writing - review & editing. **James N. Sanchirico:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Supervision, Writing - review & editing. **J. Edward Taylor:** Conceptualization, Funding acquisition, Investigation, Methodology, Project administration, Software, Supervision, Writing - review & editing.

Acknowledgements

We are grateful for funding from the World Bank GEF CCRES project (P123933), The David and Lucile Packard Foundation grant 2014–40350, and the National Institute of Food and Agriculture (NIFA). Taylor and Sanchirico are members of the Giannini Foundation of Agricultural Economics. We thank J. E. Wilen for feedback on an earlier version of this paper, and A. Gonzales, P. Regoniel, and other partners at Palawan State University. We thank A. Rogers, P. Mumby, C. Smith and R. Richards for information about the field site. We also thank two anonymous reviewers for their helpful suggestions on improving the paper.

Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.jenvman.2020.110968.

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