A Bioeconomic Local General Equilibrium Assessment of Distributional Consequences of Small-Scale Fisheries Reform in Developing Countries

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ABSTRACT

Fisheries reform can increase wealth created by degraded small-scale developing-world fisheries. However, empirical studies of distributional consequences of reforms are scarce. Previous empirical studies largely focus on the fishing sector in isolation or do not disaggregate households into socioeconomic groups. We assess the distributional consequences of a fishery reform using a bioeconomic local general equilibrium model estimated and calibrated with data from a Philippine municipality. We disaggregate households into fishing and nonfishing households with different income levels. Fishing households overcome initial losses as the fish stock recovers, with wealthier fishing households attaining larger absolute gains. Nonfishing households suffer negative spillovers and higher fish prices, and gain only moderately as the fish stock recovers, leaving them worse off over the 20-year period assessed. Our results suggest a need for complementary policies to redress short-run losses and heterogeneous outcomes across households. We also examine how trade mediates the impacts of the reform.

Key words: Economic development, fisheries reform, general equilibrium, poverty, small-scale fisheries.
JEL codes: Q22, Q56.

INTRODUCTION

Small-scale fisheries reform represents an opportunity to strengthen local economies over time in developing countries.[1] Fishing often is a significant source of protein and income for coastal

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1. In this paper we use the term small-scale fisheries to refer to fisheries characterized by a large number of fishers in relatively small boats in the nearshore environment in developing countries. This is to distinguish them from commercial-scale offshore fishing operations, which also exist in developing countries. Other similar terms used in the literature include "artisanal fisheries" and "small-scale, nearshore artisanal fisheries."

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communities in developing countries. It also creates benefits by supporting industries (e.g., post-harvest processing) and nonfishing households that consume fish (Béné, Macfadyen, and Allison 2004; Kawarazuka and Béné 2010). For small-scale marine fisheries in developing countries, the World Bank estimated that, in 2012, total catch was 28 million tons; the small-scale fishing sector employed 13 million fishers and 37 million people in post-harvest when one includes both full- and part-time workers (World Bank 2012). However, problems such as overharvesting reduce the economic contributions that small-scale fisheries make to local economies (Béné, Macfadyen, and Allison 2004).

In developed countries, market-based fisheries reform has reduced overharvesting, generated economic value (e.g., higher revenues and lower fishing costs), and created additional benefits such as a reduction in occupational risks (Homans and Wilen 2005; Pfeiffer and Gratz 2016; Birkenbach, Kaczan, and Smith 2017). Successful reforms in developed countries have spurred support for instituting similar reforms in developing countries to help generate wealth and reduce poverty (Cunningham et al. 2009). Institutions such as individual transferable quotas (ITQs), Territorial Use Rights for Fisheries (TURFs), and direct limits on fishing effort have been implemented in developing countries as in developed countries (Jardine and Sanchirico 2012). However, reforming fisheries in rural and often isolated areas in developing countries brings new challenges. The effects of reforms may be different for poor than for nonpoor fishing households, and changes in the quantity of fish production may affect the local price of fish, with consequences for businesses and nonfishing households that purchase fish (Wilen 2013; Manning, Taylor, and Wilen 2018). The acceptability of reform efforts in developing countries depends in part on the distributional consequences for local stakeholders (Cunningham et al. 2009).

A series of theoretical papers employing two-sector models examine how small-scale fisheries reform in developing countries can be expected to affect fisheries, local economies, and the poor. They show that reforms in developing-country fisheries cannot be modeled using a single-sector framework because the value of factor inputs' alternative income opportunities influences the outcome of reforms. Scott (1957) uses a two-sector model (fishing and agriculture) with fixed prices and fixed total factor supplies to illustrate a move from open access to efficient management by a hypothetical sole owner or an efficient cooperative. Economic efficiency in this static model implies hiring labor in the fishery only up to the point where the value of the marginal product of labor is equal to the wage rate. This causes labor to reallocate to the farming sector and the wage rate in the economy to decrease. The value of the total product in the economy is larger under the reform, and with proper redistribution, everyone could be better off. Welfare outcomes, however, depend on the initial distribution of property rights and institutional arrangements governing who receives newly created economic returns. Building on the work of Scott (1957) and others, Wilen (2013) shows the need to account for how the stock recovery would affect future productivity in the fishery.

Empirical assessments of small-scale fisheries reform in developing countries are limited in the peer-reviewed literature (Johnson et al. 2013). Studies focused on the fishing sector find that reforms can increase the sector's contribution to GDP and facilitate stock recovery (Oelofsen 1999; Cancino 2007; Coulthard 2011; Kroetz et al. 2017). However, these studies are largely limited to the fishing sector and do not shed light on the broader distributional consequences of reforms. Manning, Taylor, and Wilen (2018) develop an empirical bioeconomic local computable general equilibrium (CGE) model for a Honduran fishing village to illustrate the general equilibrium effects of restricting the amount of fishing capital. The economy's representative household suffers an income loss in the short run but reaps an income gain in the long run as the fish biomass recovers. Their analysis illustrates the importance of accounting for general equilibrium effects (e.g., local price changes and cross-sector linkages) when assessing fisheries reform in developing countries, but it does not provide insights into how reforms may have heterogeneous impacts across different households, including nonfishing households.

The contribution of this paper is to empirically assess the distributional consequences of a small-scale fishery reform in a developing-country setting using a bioeconomic local CGE modeling framework. This framework links a local general equilibrium model to a bioeconomic model of a fishery and is estimated and calibrated with household survey data, similar to Gilliland, Sanchirico, and Taylor (2019). Our local general equilibrium model builds on the agricultural household modeling framework utilized in development economics, in which household groups are producers and consumers (Taylor and Filipski, 2014, 34). This framework permits an assessment of reform impacts in developing-world settings where poverty, producer-consumer households, and market imperfections are common—factors that limit the scope of transferring results from developed-world studies (e.g., Finnoff and Tschirhart 2008). A local general equilibrium model is at the scale of a village or small geographic region, as opposed to national-scale or regional-scale models that are more common in the literature. Our model disaggregates households into four representative household groups based on their fishing status (fishing/nonfishing) and whether they are above or below the poverty threshold (poor/nonpoor). We econometrically estimate parameters and calibrate the model using a novel dataset from surveys of 464 households, 282 businesses, and 433 tourists conducted in 2015 in a municipality of the western Philippines.

Our empirical approach provides a complement to theoretical assessments of the impacts of fisheries reform. Empirical results support and validate hypotheses generated by theoretical models. The modeling framework we use incorporates a broader array of GE effects and cross-sector interactions than previous theoretical models—effects and interactions that are important in studying small-scale fisheries in developing countries (Manning, Taylor, and Wilen 2018). Empirical models help sign as well as quantify the magnitudes of impacts. While empirical models and their results are necessarily more specific to a particular case, our chosen case site has many characteristics in common with other developing-country contexts, including high levels of exploitation of the fish stock, low incomes, and a mix of fishing and nonfishing households at different income levels. We examine the implications of different trade scenarios to broaden the applicability of our results.

To simulate a fishery reform within our bioeconomic local CGE framework, we model a transition from open access, where externalities from stock impacts are ignored, to a reformed fishery, where the effective price used to determine labor demands is adjusted downward to account for the fact that harvesting decreases a productive input, the fish stock. Specifically, in the labor demand equations under the reform, the per-unit value added attributable to the resource stock is subtracted from the fish output price. This is similar to how, in a dynamically efficient fishery, the optimal shadow value of the stock would be subtracted from the output price, though in our context it is not possible to calculate the optimal shadow value of the stock because of model complexity (e.g., multiple sectors with endogenous prices). We find that on an aggregate level, the reform causes short-term losses due to reduced production in the fishing sector and higher fish prices, but a recovery of the fish stock creates long-term gains. The fishery reform has heterogeneous impacts across socioeconomic groups. In the short run, all households experience lower real incomes, but the stock recovery is sufficient to make fishing households better off in the long run, particularly nonpoor fishing households that own more fishing capital. Nonfishing households, both poor and nonpoor, benefit only indirectly from the stock recovery; in present-value terms, they are worse off over the 20-year period we examine.

It is frequently the case that trade-offs exist between efficiency and other social objectives (e.g., Kroetz, Sanchirico, and Lew 2015). Our results suggest a need to complement small-scale fisheries reform with policies that redress short-run losses and heterogeneous adjustment costs across different socioeconomic groups. We also show that trade mediates the impacts of the reform. Trade provides a substitute for locally produced fish when the reform reduces local production. Accounting for trade possibilities can inform efforts to mitigate the adjustment costs of reforms.

The rest of the paper is organized as follows. The next section describes the bioeconomic local general equilibrium model and how we use it to model open access and the fishery reform. The case study section discusses the field site in the Philippines, survey data, and model parameterization. The results section presents results of the simulated fishery reform, including different trade contexts and sensitivity analyses. Finally, the last section discusses conclusions and policy implications of our results.

MODELING FRAMEWORK

Our empirical modeling framework links a bioeconomic model and a local computable general equilibrium (CGE) model estimated and calibrated for a small-scale nearshore fishery embedded in a local economy (Manning, Taylor, and Wilen 2018; Gilliland, Sanchirico, and Taylor 2019; Lindsay et al. 2020). The local CGE model is based on the agricultural household modeling framework found in Taylor and Filipski (2014, 34). For a listing of all model equations, see online appendix tables A1–A5.

PRODUCTION

Household production technologies for all goods take the Cobb-Douglas form. For fishing activities, production is also a function of the fish stock size, so the household value-added production function for fishing is

$$QP_{h,t} vash_h = AL_{FL,h,t}^{\beta_{FL}} L_{HL,h,t}^{\beta_{HL}} K_{h,t}^{\beta_K} X_t^{\beta_X}, \tag{1}$$

where $QP_{h,t}$ is quantity produced at time t by household h, $vash_h$ is 1 minus the share of intermediate inputs in the output price, A is a shift parameter, L indicates labor usage, FL and HL subscripts denote family and hired labor, K is capital usage, X_t is the fish stock size, and the β parameters are output elasticities. We assume constant returns to scale for nonfishing activities. For the fishing activity, we assume constant returns to scale for the economic factors ($\beta_{FL} + \beta_{HL} + \beta_K = 1$) and increasing returns to scale across the economic factors and stock input, as has been shown in other fisheries (e.g., Hannesson, 1983; Harley, Myers, and Dunn 2001; Ekerhovd and Gordon 2013). Cobb-Douglas production technology is a common assumption in the bioeconomic CGE and fisheries economics literature (Doll 1988; Bjørndal 1989; Manning, Taylor, and Wilen 2018; Gilliland, Sanchirico, and Taylor 2019; Lindsay et al. 2020); however, future work would benefit from exploring other functional forms.

Standard profit maximization procedures are used to derive demands for factors except in the fishery, which is discussed below. Within a time step, fishing households treat the fish stock as a fixed value. The time step in the model is one year. For the production activities, we model intermediate input demands as Leontief (constant input-output ratios). This means that the demand for an intermediate good (such as fish for a restaurant) is proportional to output (meals served).

FISHING LABOR ALLOCATION UNDER OPEN ACCESS

We assume that in open access, individuals in the fishery are not forward-looking or strategic in their decisions about how much effort to allocate to fishing. They do not take into account how their actions may affect the fish stock and productivity in the future or how the actions of others will impact their ability to catch fish in the current period. This means fishers ignore the shadow value of the fish stock. These assumptions are consistent with an open-access setting with many fishing agents acting independently with little information sharing. A fishing household's first-order conditions for fishing factor demands under open access can be written as

$$W_{FL,h,t} = PVA_{h,t} \frac{\partial QP_{h,t}}{\partial L_{FL,h,t}}, \tag{2}$$

$$W_{HL,t} = PVA_{h,t} \frac{\partial QP_{h,t}}{\partial L_{HL,h,t}}, \tag{3}$$

$$R_{K,h,t} = PVA_{h,t} \frac{\partial QP_{h,t}}{\partial K_{h,t}}, \tag{4}$$

where W and R denote wages and rental rate, and $PVA_{h,t}$ is the price of value added, or the output price per unit minus the cost of intermediate inputs used to produce that unit. The fishing households all have the same production technology, with constant returns to scale across the economic factors, ensuring that there are zero economic profits. This model assumes that effort enters the fishery instantaneously at each time period, as opposed to models that assume effort enters a resource sector slowly (Smith 1968).

FISHING LABOR ALLOCATION UNDER THE FISHERY REFORM

An economically efficient fishery reform would require subtracting the optimal shadow value of the fish stock, λ_t, from the fish price of value added in each time period, leading to the optimal level of harvest (Wilen 2013). This internalizes the externality associated with the fact that each unit of harvest reduces one of the productive factors, the stock. However, it is not straightforward to solve for λ_t in the context of a bioeconomic local CGE model with multiple sectors with endogenous prices. In this paper, we instead model a fishery reform by subtracting from the output price the share of value added that is attributable to the resource stock.[2] As discussed in the bioeconomic local general equilibrium model in Manning, Taylor, and Wilen (2018), under open access, labor and capital appropriate all of the value added created by the fishing production

2. An alternative approach would be to calculate the optimal steady state of the economy and associated optimal steady-state shadow value, λ_{ss}. Subtracting λ_{ss} from the fish output price would lead the economy to the optimal long-run equilibrium, albeit via a nonoptimal approach path. Given the pervasiveness of market imperfections in local rural economies in the developing world, λ_{ss} would likely need to be solved for within a GE context with endogenous prices for fish, intermediate inputs, and factor inputs. Future work should consider this approach to modeling the reform.

process, even though some of that value added is attributable to the resource stock. This leads to an overallocation of fishing effort, which is inefficient. To identify the share of value added that is attributable to the resource stock, we can use Euler's theorem on homogeneous functions (Lewis 1969, 297–303) to write

$$\alpha PVA\ QP = PVA\ L_{FL} \frac{\partial QP}{\partial L_{FL}} + PVA\ L_{HL} \frac{\partial QP}{\partial L_{HL}} + PVA\ K \frac{\partial QP}{\partial K} + PVA\ X \frac{\partial QP}{\partial X}, \quad (5)$$

where α is the degree of homogeneity of the production function, with household and time subscripts suppressed to simplify exposition. This can be rewritten as

$$\alpha PVA\ QP = \beta_{FL} PVA\ QP + \beta_{HL} PVA\ QP + \beta_K PVA\ QP + \beta_X PVA\ QP. \quad (6)$$

If the production function were constant returns to scale with respect to all factors, meaning all output elasticities sum to unity and $\alpha = 1$, the output elasticities would represent the share of value added attributable to the corresponding factor. However, under increasing returns to scale, as is the case for many fishing production processes, $\alpha > 1$. Equation 6 can be rewritten as

$$PVA\ QP = \beta_{FL}\alpha^{-1} PVA\ QP + \beta_{HL}\alpha^{-1} PVA\ QP + \beta_K\alpha^{-1} PVA\ QP + \beta_X\alpha^{-1} PVA\ QP, \quad (7)$$

where now the output elasticity divided by the degree of homogeneity represents the share of value added attributable to the factor. For one unit of fishing output, $\beta_X\alpha^{-1}PVA$ represents the value added that is attributable to the resource stock. Similar to how traditional resource rents are generated by more than just the resource—they are also a function of technology, prices, and other factors (Arnason et al. 2018)—what we denote as the value added attributable to the stock is also determined by other factors such as technology and prices.

Using this formulation, we model a reform by setting the labor allocation conditions to the following:

$$W_{FL,h,t} = \left(PVA_{h,t} - \beta_X\alpha^{-1}PVA_{h,t}\right) \frac{\partial QP_{h,t}}{\partial L_{FL,h,t}}. \quad (8)$$

$$W_{HL,t} = \left(PVA_{h,t} - \beta_X\alpha^{-1}PVA_{h,t}\right) \frac{\partial QP_{h,t}}{\partial L_{HL,h,t}}. \quad (9)$$

In these first-order conditions, the per-unit value added attributable to the resource stock is subtracted from the price of value added because producing one unit of fish reduces the resource stock's biomass level. This means that the effective price of value added, $PVA_{h,t} - \beta_X\alpha^{-1}PVA_{h,t}$, that appears in the first-order condition above is the share of the original price of value added that is attributable to all non-stock factor inputs. Note that because the price of value added is endogenous in our model (the price of fish and fishing inputs are endogenous), the value added attributable to the resource stock also adjusts when the price of value added changes. This formulation of reform will not produce the dynamically efficient harvesting schedule as would the solution to an optimal control problem, but it is likely a feasible approach in small-scale fisheries of developing countries that face substantial market imperfections, endogenous prices, limited data inputs, and limited management resources. In our Philippine case study, the reform adjusts the price of value added downward by 39.2% (i.e., $\beta_X\alpha^{-1} = 0.392$). Given that the optimal shadow cost of the stock is not known, in the sensitivity analysis section, we examine model results for a range of different shares subtracted from the price of value added.

We maintain capital as fixed under the reform, making the reform akin to an agreement in which additional capitalization and new entrants are not permitted, and where there are not well-functioning capital markets. For longer-run analyses, modeling dynamically efficient capital allocations could provide a useful extension to this modeling framework. If functioning capital markets were included in the model and fishing capital were reduced as part of the reform, this would entail a greater initial reduction in fishing pressure because there is also an overallocation of fishing capital under open access.

Each representative fishing household collects the newly created profits from its own fishing activities, equal to revenue less intermediate input costs and opportunity costs of factors. This differs from the modeling framework in studies that assume fishers are purely laborers (e.g., Scott 1957; Wilen 2013), and it is a reflection of the fact that fishers in nearshore, small-scale fisheries in developing countries often are independent agents and own their own small boats and gear. Given that representative households provide a picture of average livelihood strategies (e.g., capital ownership) for households within the group, we implicitly assume that additional economic returns are divided equally among households within a representative household group. In reality, there would likely be heterogeneity in the distribution of the additional returns within household groups.

CONSUMPTION

Household incomes in the local CGE model are the sum of payments to factors owned by the household plus exogenous forms of income such as cash transfers from government social welfare programs. Households are assumed to have constant elasticity of substitution utility. Household consumption demands are derived from these utility functions using standard utility maximization subject to a budget constraint.

MARKET CLOSURE ASSUMPTIONS

For goods that are not tradable, local production must equal local supply. For goods that are traded and produced in the local economy, outside and locally produced goods combine into a composite, as described by an Armington function. This allows for imperfect substitutability between outside and local goods (Armington 1969). An Armington function has the same form as a constant elasticity of substitution production function; Armington elasticities reflect the substitutability between outside goods and their locally produced counterparts. For example, in the case of imports, 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. The composite good is an input for production activities (e.g., fish to restaurants) and is consumed by households.

LINKING THE LOCAL CGE MODEL TO A BIOLOGICAL MODEL

We link the local CGE model with a dynamic fish stock model that adjusts in response to harvesting pressure. For simplicity, we assume that growth of the stock is logistic. The population dynamics for the stock take the following form:

$$X_{t+1} = X_t + \gamma X_t \left(1 - \frac{X_t}{K}\right) - \tau \sum_h QP_{h,t}, \tag{10}$$

where γ denotes the intrinsic growth rate, K is the carrying capacity, X_t is the stock level at time t, and τ is a coefficient to translate output into the correct units (kilograms). Logistic growth accounts for factors such as density dependence, but it does not account for other features of fish population dynamics known to be important, such as age classes and larval dispersal. In the absence of ecological data needed to parameterize more complex growth dynamics at this field site, we assume logistic growth, recognizing that incorporating more ecological complexity into modeling frameworks will improve efforts to assess impacts of reforms in these contexts.

We assume that as the stock increases, this will increase the marginal productivity of factor inputs and decrease search costs by lowering expenditures on fuel needed to find desired fishing locations (Wilson 1990; Eales and Wilen 1986). Search costs may be inversely related to the stock size (Jensen and Vestergaard 2003), suggesting that search costs decrease faster with stock recovery when fish stocks are low. To integrate search costs related to fuel into a local bioeconomic CGE framework, we model the intermediate demand share for retail goods like fuel as an inverse function of the stock size:

$$idsh_{h,t} = \frac{a_h}{(X_t)^n}, \tag{11}$$

where $idsh_{h,t}$ is the intermediate input demand share for retail goods (e.g., petrol) needed for fishing. The value of n reflects how quickly costs decrease as the stock increases, and a_h is calibrated from cost data. The intermediate demand share is used to subtract the per-unit cost of intermediate inputs from the output price to obtain the price of value added. Thus, as the stock increases, this decreases the intermediate demand share according to equation 11 and increases the price of value added.[3]

Within a time period, the local general equilibrium model solves for equilibrium prices and quantities in the economy conditional on a fixed fish stock level for that year, X_t. The fish stock size for the next time period is calculated according to equation 10. In the next time period, the local general equilibrium model solves conditional on the new fish stock size, and this process repeats for the number of time periods used in the analysis. The bioeconomic local CGE model described above is programed using the general algebraic modeling system (GAMS).[4]

CASE STUDY, SURVEY DATA, AND MODEL PARAMETERIZATION

We apply our model to the municipality of El Nido on the island of Palawan in the western Philippines (2015 population: 36,000), whose economy is dominated by tourism and fishing. El Nido is an ideal location to examine the distributional impacts of small-scale fisheries reform. Fishing contributes 9% to local GDP, and approximately 30% of households engage in fishing. Fishing is also a common activity for lower-income households. Fish constitute an important source of protein in the Philippines; annual per capita fish consumption in the Philippines is 32.7 kg (FAO

3. As with the stock size itself, search costs that depend inversely on the stock size are adjusted between time steps (i.e., between annual model solutions). Fishing households treat the stock size as constant within a time step, and therefore also do not account for impacts of stock size on search costs within a time period. This means that the value-added production function is homogenous within a time step.

4. The GAMS code, data input sheet, and social accounting matrix created by the calibration are available upon request.

2014). The contributions of other sectors to GDP in the El Nido economy are as follows: hotels and restaurants, 35%; tourism activities, 15%; retail stores, 23%; other services, 12%; and agriculture, 7%.

El Nido's nearshore fishery suffers from significant overfishing. The fishery is best approximated by an open-access setting with many resource users and no clearly defined property rights. 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. There are some gear restrictions; however, with the exception of cyanide and bombs, enforcement of regulations is minimal. The most common gear types used in El Nido are bottom-set gill net and hook-and-line, though some households also use drift nets and spearfish. The most commonly caught fish groups in El Nido (by weight) are tunas, mackerels, squid, and groupers.

We implemented surveys of households, businesses, and tourists in 2015. The household surveys gathered detailed data on assets, time use, net income from all production activities, salaries, transfers, expenditures, and basic demographic data. A total of 464 households were surveyed, approximately 6.2% of all households in El Nido. We weighted the number of households surveyed in each submunicipal district (barangay) by population size and stratified the sample to focus on areas where fishing and tourism-related activities—two key sectors in the El Nido economy—are more common. Households were randomly sampled within barangays. The business surveys collected detailed information on inputs, factor usage, outputs, and revenues for establishments in El Nido. A total of 282 businesses were surveyed by choosing establishments at random from a list of registered businesses obtained from local government officials. The tourist surveys collected data on how much tourists spent at different types of establishments. The 433 tourists in the sample were surveyed at points of departure to ensure that they had completed their expenditures in El Nido. We treat expenditures by tourists as exogenous to the local economy.

Using the survey data, we created four representative household groups in the model, based on whether the households engaged in fishing (fishing/nonfishing) and whether they were above or below the poverty line (poor/nonpoor).[5] Summary statistics for these household groups are in table 1. Nonresidents who own local businesses, primarily in the hotel sector, constitute an additional household group in the model. They do not live in El Nido and therefore have no local consumption expenditures.

We used survey data to designate the six primary production activities: tourism activities, fishing, hotels, retail, agriculture, and other services. We aggregate fishery products into a single good, given that fishers tend to target multiple species simultaneously by using many gear types and gears that are unselective (e.g., gill nets). El Nido is a net importer of fish and agricultural goods due in part to the elevated demand for goods from visiting tourists. Field surveys revealed that imports supplied 11% of fish and 13% of agricultural consumption in El Nido. Tourism activities (e.g., boat trips), hotel stays, spending at local retail stores, and other services are nontradable goods because they are inherently produced locally.[6]

5. We use the Philippine government's 2015 per capita poverty line (approximately USD 427 per year) for the island of Palawan. Income was approximated using detailed expenditure data given that in developing-world contexts consumption data are thought to be more reliable and better able to capture long-run welfare levels than current income (Gillis, Shoup, and Sicat 2001).

6. 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

Table 1. Summary Statistics for Households Surveyed in El Nido

Household Group (n)	Average Per Capita Consumption Expenditures (USD)[a]	Percentage Sometimes Concerned about Having Enough Food	Average Household Size	Average Adult Education Level (years)
Fishing nonpoor	779.7	2.3	4.8	6.8
(87)	(328.73)		(1.88)	(4.44)
Fishing poor	323.3	10.0	5.9	5.1
(50)	(69.36)		(2.23)	(4.00)
Nonfishing nonpoor	954.1	3.6	4.6	8.8
(221)	511.21)		(2.03)	(4.95)
Nonfishing poor	290.5	9.4	5.3	6.9
(106)	(88.28)		(2.26)	(4.61)

Note: Standard deviations are in parentheses. [a] The official provincial poverty line in 2015 was USD 432.7.

The factors of production in the economy include family labor, hired labor, capital, purchased factors such as fertilizer, and land.[7] We assume fixed capital in each economic activity, a common assumption in micro agricultural-household and GE modeling. 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 small-scale fisheries reform in developing-country contexts. Arable land in El Nido is relatively scarce due to steep terrain, so the amount of land in agriculture is considered fixed. In general, labor is able to move between different production activities within the local economy, though family labor is restricted to family-owned production activities (Thome et al. 2013; Filipski et al. 2015).

The household groups are heterogeneous with respect to production activities (online appendix table A6). Nonfishing households use more fishing capital than do poor fishing households and also have more diverse livelihood activities. Poor nonfishing households primarily engage in agriculture and retail (e.g., small corner stores). Nonpoor nonfishing households are responsible for a significant amount of production in all nonfishing activities of the economy. Nonresidents are primarily active in tourism-related sectors.

Following methodologies of recent studies using local CGE models, we employ our microsurvey data to econometrically estimate model parameters and derive initial values used in the model calibration; this method differs from the traditional approach of obtaining aggregate shares from social accounting matrices (Taylor and Filipski 2014, 190; Gilliland, Sanchirico, and Taylor 2019). We estimate demand parameters for each household group, but for production parameters, we pool observations because data from business surveys cannot be assigned to specific household groups (online appendix tables A7 and A8). This implies that all households engaged in a production activity share the same production technology.

For parameters that could not be estimated, we draw values from the literature or relevant contextual information collected at the field site. For the fishery production function, we are not able to estimate the stock elasticity because of a lack of adequate data, as is typically the case

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.

7. 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, similar to other local CGE models of rural economies in developing countries (e.g., Thome et al. 2013; Filipski et al. 2015).

in developing-world fisheries. We use results from studies that estimate stock elasticities in other fisheries to inform our choice of this parameter value. Burgess et al. (2017) provide a recent review of existing literature on stock elasticity estimates, which includes 39 estimates for aquatic species from 24 sources (see Burgess et al. [2017] supplemental information for details). Excluding species not relevant for our system (e.g., marine mammals, prawns, and freshwater species), 28 estimates remain, with a median stock elasticity value of 0.620. Additional papers estimating stock elasticities include Hannesson (1983), which examines the Lofoten fishery (cod) in Norway, finding a stock elasticity for the aggregate fishery of 0.762 (averaged across different effort definitions). For a herring fishery in the North Sea, Bjørndal (1987) gives estimates of 0.34–0.62 depending on model specification, noting that results are not significantly different from 1. Ekerhovd and Gordon (2013) provide estimates for cod and saithe using data from the International Council for the Exploration of the Sea. Averaged across the periods examined, they find stock elasticities of 0.972 for cod and 0.886 for saithe. Including these additional studies with the values provided in Burgess et al. (2017) results in a median stock elasticity value of 0.645, which we use as the value for our stock elasticity parameter in the model. Generally, the stock elasticity is assumed to be higher for demersal species spread more evenly across the landscape and lower for species that have aggregating or schooling behavior that would cause hyperstability of catch per unit of effort (Burgess et al. 2017). The value of 0.645 is likely an appropriate estimate for our system given that it has both schooling fish (e.g., skipjack tuna) and demersal reef fish. Uncertainty about the size of this parameter is compounded by the fact that much of the empirical literature on stock elasticities uses data from industrialized fisheries in northern oceans, rather than small-scale fisheries in tropical oceans. Given this uncertainty, we include a sensitivity analysis that provides results using the first and third quartiles of the stock elasticity estimates (see the sensitivity analyses section).

For the fish and agricultural goods imported into El Nido, trade is hampered by factors such as poor transportation infrastructure and low-quality ice that may affect the quality and freshness of imports. We designate the baseline case as a “moderately integrated” trade scenario, in which Armington functions control the substitutability between imports and locally produced goods. Choosing Armington elasticities is challenging because of the small geographic focus of the model. Armington elasticity values that exist in the literature are typically at the scale of a country or large geographic region, rather than a village or small municipality. At the country level, there is likely less substitutability between domestically produced goods and goods imported from other countries. For example, fish imported from other countries are 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, individuals sourcing fish from outside El Nido reported sourcing fish of the same species that were 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 tend to flow more easily over local and state boundaries than over national ones (Anderson and Van Wincoop 2003). National-level values reported for fish range from 0.82 to 2.8, and values for agricultural goods range from 1.03 to 6 (Hertel 1997; Annabi, Cockburn, and Decaluwé 2006). We set the Armington elasticities at a value of 8 for both of these good types and, given uncertainty about parameter values, we examine a range of different elasticities to explore how simulation results change under different assumptions. This provides an opportunity to examine how localities with different local trade scenarios may vary in how they are affected by fisheries reform.

Since poor households spend a substantial portion of their income on food, the model allows households to substitute away from sources of food that become relatively more expensive according to constant elasticity of substitution utility functions. The exact elasticities of substitution are not known at this site. We use a relatively high value of 3 to reflect that poor households are likely willing to substitute toward cheaper food items as prices rise, and a sensitivity analysis is performed to explore how results change under different specifications. Tourists are also assumed to exhibit a high level of substitutability given that their purchases are of nonessential items such as boat tours. The elasticity of substitution in consumption for tourists is set to 3 and included in the sensitivity analysis.

In the biological system, we set the initial stock size at 36% of carrying capacity, based on preliminary ecological surveys from the El Nido region and fisheries literature reporting that nearshore fish stocks in developing countries tend to be characterized by similarly high levels of exploitation and low biomass (Bailey and Pitcher 2008; Worm et al. 2009; Kellner et al. 2011).[8] Given the challenge of estimating an intrinsic growth rate for an aggregate fish stock, we assume a growth rate of 0.50, as this is an intermediate value of productivity for fish populations (Manning, Taylor, and Wilen 2018).

The search cost function (equation 11) determines how input costs for fishing decrease as the size of the fish stock increases. In this function, the parameter a_h is calibrated to reproduce the baseline level of input costs measured in the household surveys. The exact relationship between intermediate input costs and the stock size is not known; in the model we assume that $n = 1$ and perform a sensitivity analysis to illustrate how results change if search costs related to intermediate inputs are more or less sensitive to changes in the stock size.

We assume no migration; that is, the number of households is fixed. Thus, the paper does not address the possibility of new fishers entering the area in response to a recovering fish stock. Cinner (2009) discusses such migration, but notes that outcomes range from migrants being largely excluded by existing institutions to migrants weakening or collapsing local resource institutions. If migrants were to enter a local area and overwhelm local resource management institutions, this would lead to different outcomes than we find. Likewise, it is well established that population growth can threaten resource management institutions (Ostrom 1990, 143), which could also lead to different outcomes. There is significant unemployment (14%) and underemployment in this area (PEP-CBMS 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 to test for robustness of simulation results.

RESULTS

Below we show how the reform affects the fish stock, household incomes, and other local economic variables over time. We first show these results for the base parameter values discussed in the previous section, the "moderately integrated" trade scenario. We then examine two alternate scenarios, "highly integrated" and "isolated" trade scenarios, and perform sensitivity analyses.

8. Alice Rogers (director, Wellington University Coastal Ecology Laboratory), email message to authors, September 1, 2016.

MAIN RESULTS

Table 2 shows the impact on fish biomass and local economic variables in year 1 and year 20 of the simulation. We illustrate results for a 20-year time frame to allow time for the stock dynamics to take effect but avoid extending the analysis beyond this point given that the model does not account for longer-term factors such as structural changes in the economy or investment. The middle columns contain results for the moderately integrated trade scenario, which best represents our field site.

In year 1, the reform reduces the amount of fishing labor, decreases fishing output, and increases the price of fish (table 2). Consistent with predictions from the theoretical literature, fishing households experience a reduction in their factor incomes from fishing (Scott 1957; figure 1). This reduces households' real incomes, particularly for fishing households, which depend closely on fishing for their livelihoods. In year 1, nonpoor and poor fishing households see declines in real income of 10.94% and 13.57%, respectively. Larger percentage declines for poor fishing households are due in part to their less diverse livelihood activities (online appendix table A6). Fishing households receive new profits from the fishery reform, equal to revenue less intermediate input costs and opportunity costs of factors; however, immediately after the reform, this is

Table 2. Impacts of the Fishery Reform on Fish Biomass (percentage of carrying capacity, K) and Local Economic Variables (percentage change from baseline) for Different Trade Scenarios

	Highly Integrated		Moderately Integrated (Base Case)		Isolated	
	Year		Year		Year	
Trade Scenario	1	20	1	20	1	20
Fish biomass (% of K)	36.00	56.68	36.00	57.52	36.00	57.78
Family fishing labor						
Fishing nonpoor	–73.97	–29.64	–54.96	–31.26	–37.95	–32.00
Fishing poor	–73.86	–29.58	–54.86	–31.19	–37.87	–31.93
Hired fishing labor						
Fishing nonpoor	–74.19	–29.82	–55.20	–31.45	–38.16	–32.19
Fishing poor	–74.13	–29.78	–55.14	–31.41	–38.11	–32.15
Fish production	–58.39	6.57	–40.52	5.97	–26.72	5.54
Fish price	1.12	–0.17	19.27	–1.92	31.83	–2.57
Fish imports	287.90	–23.76	143.60	–9.23	0.00	0.00
Real income						
Fishing nonpoor	–21.83	7.62	–10.94	6.90	–1.60	6.61
Fishing poor	–26.67	9.37	–13.57	8.54	–2.47	8.22
Nonfishing nonpoor	–7.24	0.19	–5.38	0.08	–3.49	0.01
Nonfishing poor	–9.67	–0.14	–7.42	–0.23	–4.86	–0.30
Nonresident	0.04	0.06	–0.59	0.12	–1.62	0.17
Family labor (shadow) wage						
Fishing nonpoor	–0.93	–0.27	–0.59	–0.29	–0.36	–0.29
Fishing poor	–1.10	–0.30	–0.68	–0.32	–0.41	–0.33
Nonfishing nonpoor	–0.08	0.01	–0.05	0.00	–0.01	0.00
Nonfishing poor	–0.13	0.01	–0.07	0.00	–0.01	0.00
Hired labor wage	–0.08	–0.01	–0.05	–0.01	–0.03	–0.01
Nominal GDP	–9.27	1.67	–4.90	1.29	–0.62	1.09

Note: Fish biomass is at 36% of carrying capacity (K) in the baseline. The middle two columns are results from the trade scenario for our field site (moderately integrated); this scenario uses Armington trade elasticities of 8 (see the case study section). The highly integrated scenario uses Armington elasticities of 200, and the isolated scenario makes fish and agricultural goods nontradable.

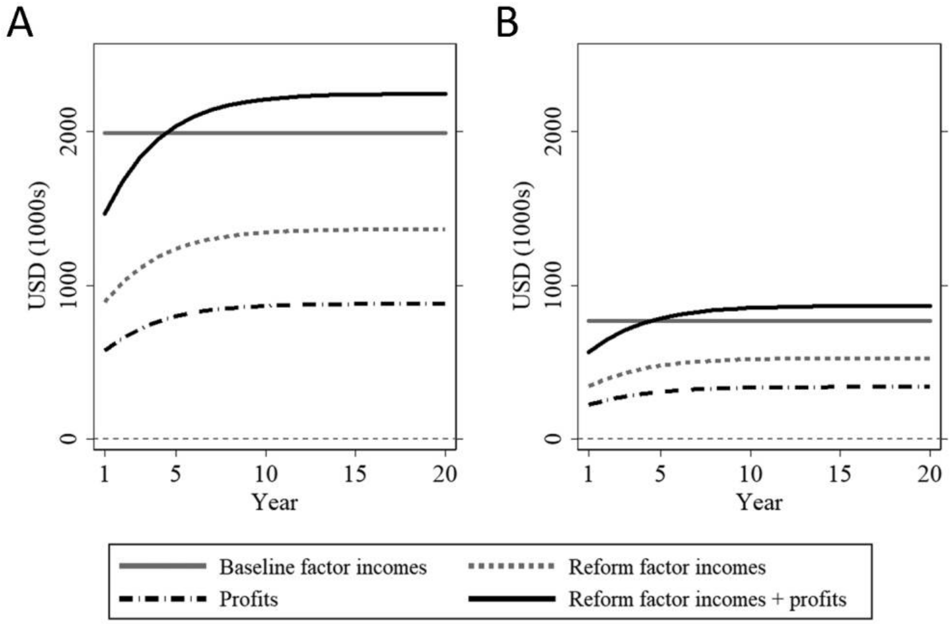

Figure 1. Impact of the Fishery Reform on Representative Household Fishing Factor Incomes and Economic Returns Created by the Reform (USD 1,000s) in the Moderately Integrated Trade Scenario. (A) Fishing nonpoor. (B) Fishing poor.

not enough to overcome the decrease in fishing factor incomes (figure 1). The theoretical literature has also concluded that in the short run, new returns in the fishery from rationalization may not be enough to compensate for losses (Wilen 2013). Note that because of a high labor supply elasticity, the reduction in fishing factor incomes derives mostly from labor leaving the fishing sector rather than from a reduction in wages (table 2).

Nonfishing households suffer smaller initial losses, the result of negative economic spillovers such as higher fish prices and lower demand for goods and services they supply. In year 1, nonpoor and poor nonfishing households see declines in real income of 5.38% and 7.42%, respectively. Nonresident households primarily own businesses that are patronized by tourists, such as hotels and tour operations. Given that tourism expenditures are exogenous in the model, nonresidents feel relatively little impact from the reform.[9]

The decrease in local fish harvest causes a recovery of the fish stock (solid black line, figure 2), the effects of which ripple through the local economy over time. As the stock size increases, fishing productivity increases and labor reenters the fishery, raising incomes for fishers (figure 1). This eventually results in real incomes above baseline levels for all fishing households (table 2 and figure 3). In year 20, nonpoor and poor fishing households experience real incomes 6.90% and 8.54% above baseline levels, respectively. Nonfishing households also benefit from the stock recovery, though their benefits are smaller given that they are indirect, via economic spillovers such

9. Note that if tourism expenditures were endogenous to some measure of environmental quality that were affected by the reform, it is likely that nonresidents would be more substantively affected. For example, if the reform leads to higher fish stocks that lead to higher-quality reefs, then we would expect increased tourism expenditures at tourism-related businesses, many of which are owned by nonresidents.

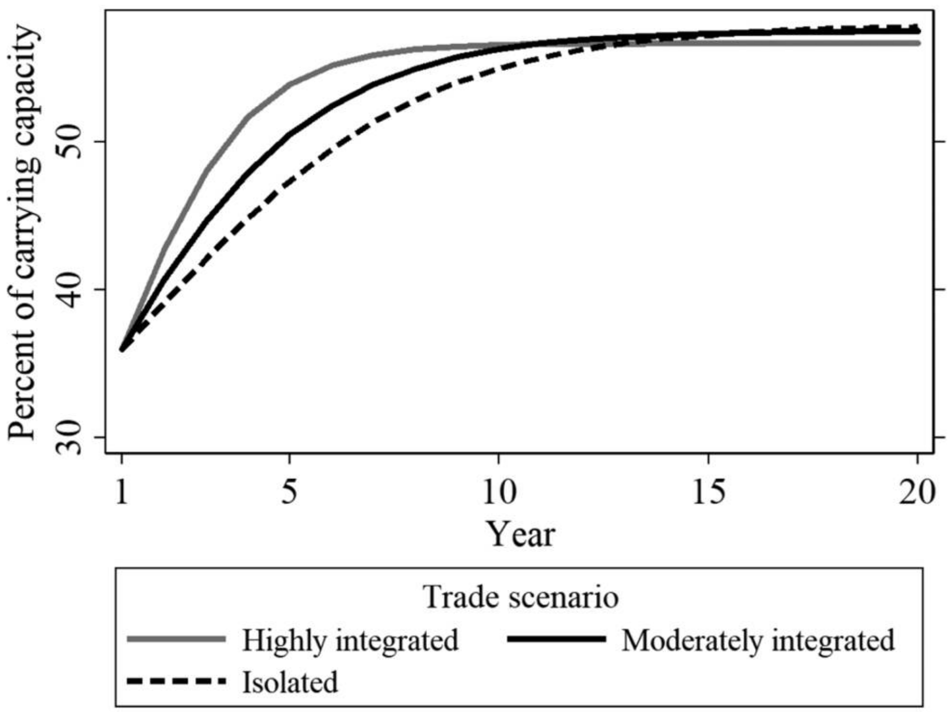

Figure 2. Impact of the Fishery Reform on the Fish Stock. The values are presented as a percentage of carrying capacity. The baseline stock size is 36% of carrying capacity. The middle solid black line represents results from the trade scenario for our field site (moderately integrated); this scenario uses Armington trade elasticities of 8 (see the case study section). The highly integrated scenario uses Armington elasticities of 200, and the isolated scenario makes fish and agricultural goods nontradable.

as lower fish prices (which eventually fall below baseline) and a healthier local economy. In year 20, real incomes for nonpoor and poor nonfishing households return very close to baseline levels (table 2 and figure 3). On an aggregate level, nominal local GDP initially falls 4.90% below baseline, but as the fish stock recovers it increases to 1.29% above baseline by year 20.

Given that incomes are changing over time, the choice of time horizon affects the present value (PV) of the reform to households, calculated as the difference between the PV of a household's per capita real income stream over a given number of years with and without the reform. Figure 4 presents the PV of the reform to households for various time horizons. We assume a discount rate of 0.05. The first time the PV of the reform is positive for fishing households is at a time horizon of 11 years. The PV is always negative for nonfishing households. With a time horizon of 20 years, nonpoor and poor fishing households attain per capita PV gains of USD 243 and USD 123, respectively (table 3). Nonpoor fishing households benefit most, suggesting that fishing households with higher levels of capital stand to benefit the most from reform. Nonpoor and poor nonfishing households see per capita PV losses of USD 145 and USD 75, respectively.

Previous work has discussed the need for complementary policies to offset social adjustment costs of reforms (Arnason, Kelleher, and Willmann 2009). Our findings on the distributional consequences of reform show how assistance may need to be allocated across fishing and nonfishing households of different income levels, and the timescale needed for each group. The needs

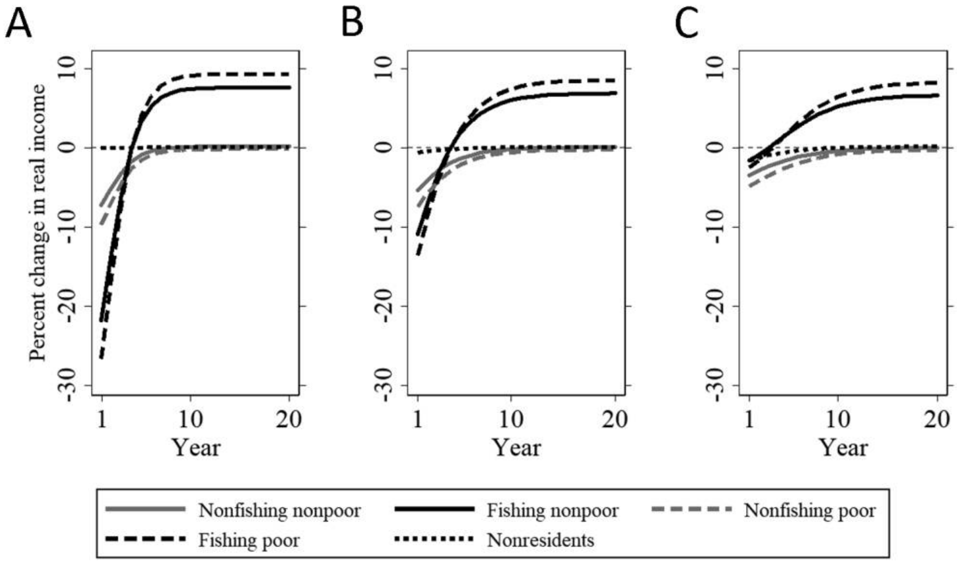

Figure 3. Impact of the Fishery Reform on Household Real Incomes (percentage change relative to baseline income). (A) Highly integrated. (B) Moderately integrated. (C) Isolated. The middle panel contains results from the trade scenario for our field site (moderately integrated); this scenario uses Armington trade elasticities of 8 (see the case study section). The highly integrated scenario uses Armington elasticities of 200, and the isolated scenario makes fish and agricultural goods nontradable.

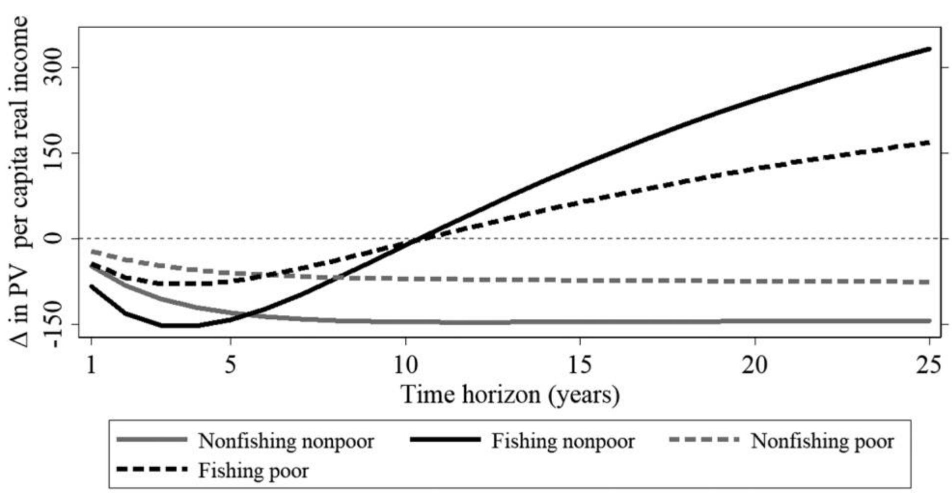

Figure 4. Change in the Present Value (PV) of Per Capita Real Income (US dollars) as a Result of the Fishery Reform for Different Model Time Horizons. For example, values for year 20 represent the reform's impact on PV per capita real income using a model time horizon of 20 years. Results are for the moderately integrated trade scenario with a discount rate of 0.05. Nonresidents could not be surveyed in the household survey, so it is not possible to calculate per capita values for this group.

Table 3. Change in Present Value of Per Capita Real Income (US dollars) for a 20-Year Period as a Result of the Fishery Reform

Trade Scenario	Highly Integrated	Moderately Integrated	Isolated
Fishing nonpoor	183	243	347
Fishing poor	94	123	171
Nonfishing nonpoor	–148	–145	–126
Nonfishing poor	–75	–75	–67

Note: These results assume a discount rate of 0.05. Nonresidents could not be surveyed in the household survey, so it is not possible to calculate per capita values for this group. The middle column contains results from the trade scenario for our field site (moderately integrated); this scenario uses Armington trade elasticities of 8 (see the case study section). The highly integrated scenario uses Armington elasticities of 200, and the isolated scenario makes fish and agricultural goods nontradable.

of fishing households may be correlated with income status, and nonfishing households could require assistance to offset initial negative economic spillovers.

THE INFLUENCE OF TRADE

Given that trade can mediate the impacts of local economic shocks (Donaldson 2010), we examine how the impacts of the reform vary depending on the local trade context. We change the degree to which this net-importing economy can substitute imported fish for locally caught fish by varying Armington elasticities. In the highly integrated scenario, imports are near-perfect substitutes for locally produced goods. In the isolated scenario, imports are not substitutable with locally produced goods. The Armington trade elasticities were changed for both fish and agricultural goods since features of a local economy that facilitate the availability of fresh imports that are close substitutes for local goods (such as better roads, food preservation, and trade relationships with outside producers) likely would affect both categories of goods.

If imported fish are near-perfect substitutes for locally caught fish (highly integrated trade scenario), relative to the moderately integrated scenario imports more easily replace cuts in local fish production, which leads to a smaller increase in the price of fish and larger cuts in the local production of fish (table 2). The larger cutback in local fish production leads to a faster initial recovery of the fish stock in the highly integrated scenario (figure 2).

Alternatively, if substitutes for locally caught fish are not available (isolated scenario), relative to the moderately integrated scenario there is a larger increase in the price of fish because of the lack of available substitutes. This leads to a smaller reduction in fishing labor, a smaller decrease in fish production, and a slower initial recovery of the stock (table 2; figure 2).

Immediately after the reform, the real incomes of all resident households are lower when imported fish are closer substitutes for local fish. This results from a greater cutback in the local production of fish and more expenditures flowing to fish-exporting regions rather than to local fishing households. Nonresidents, on the other hand, are slightly better off when there is greater access to trade; their consumption expenditures are made outside of the local economy, and they benefit from less price inflation for inputs in their businesses. When imported fish are closer substitutes for local fish, real incomes rise faster because the fish stock recovers more quickly immediately after the reform (figures 2 and 3). In terms of dollar value impact, access to trade simultaneously causes larger local production cutbacks and a faster initial recovery of the fish stock (table 2; figure 2), which have opposing impacts on the incomes of resident households.

However, the negative impacts of larger initial cutbacks to fish production outweigh the relatively moderate increase in the speed of the stock recovery. All resident households experience worse PV results in the highly integrated scenario after 20 years (table 3). These results illustrate how trade mediates the adjustment costs associated with the reform, including the temporal distribution of impacts. Understanding these differences in magnitude and temporal distribution of effects can help efforts to address heterogeneous impacts.

The economy in our case study is a net importer of fish. If instead the local economy were a net exporter of fish, it is likely that the level of market integration would have a similar mediating effect on reform impacts. A decrease in local production could be satisfied by reducing exports without changing the local price of fish. A less sensitive fish price would lead to a larger reduction in production and larger welfare consequences relative to the isolated scenario with an endogenous fish price.

The mediating impact of trade is distinct from the broader impacts that opening up to trade would have on the economy and fish stock. Other studies show that if economies are latent importers of a natural resource, opening up to trade can reduce pressure on the local resource; but if they are latent exporters, opening to trade can increase pressure on the natural resource (Brander and Taylor 1997; Hannesson 2000). Our analysis focuses on how ex ante access to trade mediates the fishery reform, not on how opening up to trade would alter the baseline local economy and fish stock prior to implementing the reform. An additional consideration that we do not address is how trade policies such as export tariffs may mediate the impact of trade on natural resources (Flaaten and Schulz 2010).

SENSITIVITY ANALYSES

The fishery reform in this paper is modeled by subtracting from the fish price of value added the share of value added that is attributable to the resource stock (see the modeling framework section). In the base model, this share is 0.392. Online appendix figure A1 provides results of the model for a range of different shares to illustrate how larger or smaller adjustments to the price of value added affect the outcomes of the reform. Results are presented for a 20-year time horizon. When the share subtracted from the price of value added is slightly smaller than in the base model, fishing households experience larger PV gains. However, much smaller and larger shares result in lower PV income gains for fishing households. Nonfishing households are always better off under smaller adjustments to the fish price of value added. The fish stock always recovers to higher levels for larger adjustments to the price of value added. The PV results are in part determined by the choice of time horizon, given that initial costs of fishing cutbacks happen in earlier time periods and the fish stock recovery occurs in later time periods. The relatively simplistic approach to reform modeled in this paper might be more feasible in developing-world, small-scale fisheries that are data deficient and lacking in management expertise; however, more efficient reforms may be possible.

We used the median of multiple stock elasticity estimates from existing literature because the fish stock elasticity in this fishery is unknown. Additional uncertainty about the size of this parameter derives from the fact that much of the empirical literature on stock elasticities uses data from industrialized fisheries in northern oceans, rather than small-scale fisheries in tropical oceans. Online appendix table A9 presents the results of the model using the first quartile ($\beta_X = 0.490$), second quartile (i.e., median, $\beta_X = 0.645$), and third quartiles ($\beta_X = 0.929$) of stock elasticity estimates from the literature to examine how our results change for different stock elasticity values. The qualitative pattern of results is similar, but for a larger stock elasticity, the increase in the stock size results in a greater increase in fishing productivity and greater benefits for fishing households after 20 years. Note that the share of the price of value added subtracted off due to the reform is larger when the stock elasticity is larger (see the modeling framework section). Nonfishing households are worse off when the stock elasticity is larger, because of bigger initial cutbacks in the fishery and associated negative economic spillovers.

The choice of discount rate in policy contexts such as this is controversial (Moseley 2001; Drupp et al. 2018). Some suggest using a higher discount rate based on the opportunity cost of capital in developing countries (World Bank 1991). Others make a case for using a lower discount rate based on the social time preference rate (Lumley 1997). We choose an intermediate value of 0.05 and provide an expanded sensitivity analysis (online appendix table A10). Higher discount rates lead to lower PV benefits for fishing households because the costs of reducing harvest occur in early time periods and increased profits from the stock recovery occur in later time periods. Nonfishing households' future losses are more heavily discounted, leading to slightly smaller PV losses.

Labor supply elasticities are high in the base model given the high levels of reported unemployment (14%) in the region (PEP-CBMS 2011). Online appendix table A11 examines the impacts of the reform under alternate assumptions about the labor supply. When the labor supply elasticities are high, the reform-induced contraction of employment causes relatively more labor to leave the labor force. This results in a larger decline in fishery production, a larger increase in the fish price, and a greater initial reliance on fish imports. In general, fishing households are worse off after 20 years; however, a greater decrease in the production of local fish results in a larger recovery in the fish stock. When the labor supply is more inelastic, less labor leaves fishing and more of the labor that does leave is reallocated to other production activities, resulting in small increases or more moderate decreases in production in nonfishing sectors. This moderates income losses experienced in early time periods by fishing households, leading to higher PV gains. A reallocation of labor to nonfishing sectors may also be more efficient because of a general equilibrium tragedy of the commons (Manning, Taylor, and Wilen 2018).

While a highly elastic labor supply is a reasonable assumption for our case study, our results suggest that the labor supply elasticity could be an important determinant of welfare outcomes of reforms. This suggests a need to examine the labor supply elasticity as part of future empirical efforts to assess reform impacts. To date, researchers have focused attention on characterizing fishers' tendencies to exit the fishery (e.g., Cinner, Daw, and McClanahan 2009). However, our results suggest a need to understand not just whether fishers will exit the fishery, but whether they will exit the labor force, as this could affect local welfare outcomes.

We assume that increases in the fish stock decrease intermediate input costs (e.g., petrol) to reflect decreasing search costs when fish are more abundant. Online appendix table A12 illustrates a ±10% change for the parameter n in equation 11. If search costs decrease more quickly as the fish stock recovers (a larger n), labor reenters the fishery faster. This in turn leads to higher levels of fish production and a smaller recovery of the fish stock. Households in the local economy are better off if the costs of fishing decrease more quickly as the fish stock recovers.

Other foods may serve as substitutes for fish. The qualitative impacts of the reform are robust to different values of the elasticity of substitution in consumption, and changes in the magnitude of results are small (online appendix table A13). When the elasticity of substitution is larger, households substitute away from fish more readily and the price of fish is less sensitive to the reform. However, as the fish stock recovers and the fish price decreases, a greater elasticity of substitution causes households to substitute back to consuming fish more readily.

In bioeconomic models, the fish intrinsic growth rate parameter affects the dynamic responsiveness of the fish stock to changes in harvesting. Our model assumes that the bioeconomic system is at a steady state in the baseline. The assumed growth rate and initial stock's fraction of carrying capacity are used to calibrate an 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. Online appendix table A14 provides model results for different combinations of growth rate and initial stock size. The impacts of the reform are qualitatively similar, but when there is a higher fish growth rate the fish stock recovers more quickly, leading to larger PV gains for fishing households and smaller PV losses for nonfishing households.

CONCLUSIONS

This paper empirically examines the distributional consequences of small-scale fishery reform in a developing-world context using a bioeconomic local CGE model. It extends previous work that focuses on the fishing sector in isolation (e.g., Cancino 2007; Kroetz et al. 2017), employs two-sector models to assess theoretical impacts (e.g., Scott 1957; Wilen 2013), or considers aggregate, economy-wide impacts (Manning, Taylor, and Wilen 2018).

Consistent with Manning, Taylor, and Wilen (2018), we find that for the aggregate economy, a fishery reform causes short-term losses but long-term gains as the fish stock recovers. However, we show that the reform has heterogeneous impacts across socioeconomic groups. Fishing households overcome initial losses when the fish stock recovers, which is consistent with empirical studies of small-scale fisheries reform in developing countries that find management efforts can increase the economic contributions of fishing sectors (Oelofsen 1999; Cancino 2007; Kroetz et al. 2017). Nonpoor fishing households attain the largest absolute gains and poor fishing households attain the largest gains relative to their baseline income. The fishery reform makes nonfishing households slightly worse off over the 20 years of our study because indirect benefits from the fish stock recovery are not sufficient to outweigh losses due to negative spillovers in earlier periods. These results suggest a need to complement reform efforts with compensation policies that account for heterogeneous adjustment costs. In particular, compensation of fishing households may need to take into account income status, and nonfishing households could require assistance to offset initial negative income spillovers. It may be possible to use existing poverty alleviation programs (e.g., cash transfer programs) to remedy adjustment costs of fisheries reforms (Gilliland, Sanchirico, and Taylor 2019).

The case site for this study shares many characteristics with other small-scale fisheries in developing countries, such as a high level of exploitation, low household incomes, and a mix of fishing and nonfishing households at different income levels. Nevertheless, the generalizability of findings from empirical work is necessarily limited by the specific characteristics of study sites. The results of this study add to a growing body of empirical work on small-scale fisheries reform in different developing-country settings (e.g., Oelofsen 1999; Kroetz et al. 2017; Manning, Taylor, and Wilen 2018), the sum total of which, in concert with theoretical modeling, provides insights relevant for guiding fisheries reform in developing countries.

We simulate the impacts of a fishery reform by adjusting the underlying economic conditions that determine the allocation of labor to fishing. In the real world, small-scale fisheries reform is implemented via institutional change. This is particularly salient given that institutional design and challenges such as corruption, unequal power dynamics, and weak monitoring and enforcement may influence the distributional consequences of reform (Wilen 2013). For example, we find that nonpoor fishing households capture a disproportionate share of the benefits from the reform. If these households also wield a disproportionate influence over determining who receives newly created economic returns, this could result in unfavorable distributional outcomes for poor fishers. Specifically, the choice of policy mechanism, such as a tax or establishing property rights, could also influence the distribution of benefits, particularly if local power dynamics influence the distribution of the tax revenues or who receives property rights. We do not model these institutional dimensions, but future work should address them.

Findings from other studies suggest that fisheries reform can have additional benefits, such as increasing the output of higher-value fisheries products (Casey et al. 1995; Kroetz et al. 2017). Our model does not account for these effects, and therefore reform benefits could be larger than our results indicate. Furthermore, if reform takes place on a national scale, rather than in a single local fishery as modeled in this paper, such reforms could lead to structural changes in the economy such as innovation, the demand for new goods, and new investment. This could lead to a different magnitude and distribution of reform impacts than we find.

REFERENCES

Anderson, J. E., and E. van Wincoop. 2003. "Gravity with Gravitas: A Solution to the Border Puzzle." *American Economic Review* 93 (1): 170–92.

Annabi, N., J. Cockburn, and B. Decaluwé. 2006. "Functional Forms and Parametrization of CGE Models." Working Paper 2006–04, Partnership for Economic Policy, Nairobi, Kenya.

Armington, P. S. 1969. "A Theory of Demand for Products Distinguished by Place of Production." *IMF Economic Review* 16 (1): 159–78.

Arnason, R., T. Bjørndal, D. V. Gordon, and M. Bezabih. 2018. "Measuring Potential Rents in the North Sea Herring Fishery." *American Journal of Agricultural Economics* 100 (3): 889–905.

Arnason, R., K. Kelleher, and R. Willmann. 2009. *The Sunken Billions: The Economic Justification for Fisheries Reform*. Washington, DC: World Bank.

Bailey, M., and T. J. Pitcher. 2008. "Ecological and Economic Analyses of Marine Ecosystems in Bird's Head Seascape, Papua, Indonesia: II." Accessed July 17, 2019. https://open.library.ubc.ca/cIRcle/collections/facultyresearchandpublications/52383/items/1.0074743.

Béné, C., G. Macfadyen, and E. H. Allison. 2004. "Increasing the Contribution of Small-Scale Fisheries to Poverty Alleviation and Food Security." FAO Fisheries Technical Paper 48, Food and Agricultural Organization, Rome.

Birkenbach, A. M., D. J. Kaczan, and M. D. Smith. 2017. "Catch Shares Slow the Race to Fish." *Nature* 544 (7649): 223–26.

Bjørndal, T. 1987. "Production Economics and Optimal Stock Size in a North Atlantic Fishery." *Scandinavian Journal of Economics* 89 (2): 145–64.

———. 1989. "Production in a Schooling Fishery: The Case of the North Sea Herring Fishery." *Land Economics* 65 (1): 49–56.

Brander, J. A., and M. S. Taylor. 1997. "International Trade between Consumer and Conservationist Countries." *Resource and Energy Economics* 19 (4): 267–97.

Burgess, M. G., C. Costello, A. Fredston-Hermann, M. L. Pinsky, S. D. Gaines, D. Tilman, and S. Polasky. 2017. "Range Contraction Enables Harvesting to Extinction." *Proceedings of the National Academy of Sciences* 114 (15): 3945–50.

Cancino, J. P. 2007. "Collective Management and Territorial Use Rights: The Chilean Small-Scale Loco Fishery Case." PhD diss., University of California, Davis.

Casey, K. E., C. M. Dewees, B. R. Turris, and J. E. Wilen. 1995. "The Effects of Individual Vessel Quotas in the British Columbia Halibut Fishery." *Marine Resource Economics* 10 (3): 211–30.

Cinner, J. E. 2009. "Migration and Coastal Resource Use in Papua New Guinea." *Ocean and Coastal Management* 52 (8): 411–16.

Cinner, J. E., T. Daw, and T. R. McClanahan. 2009. "Socioeconomic Factors That Affect Artisanal Fishers' Readiness to Exit a Declining Fishery." *Conservation Biology* 23 (1): 124–30.

Coulthard, S. 2011. "More Than Just Access to Fish: The Pros and Cons of Fisher Participation in a Customary Marine Tenure (Padu) System under Pressure." *Marine Policy* 35 (3): 405–12.

Cunningham, S., A. E. Neiland, M. Arbuckle, and T. Bostock. 2009. "Wealth-Based Fisheries Management: Using Fisheries Wealth to Orchestrate Sound Fisheries Policy in Practice." *Marine Resource Economics* 24 (3): 271–87.

Doll, J. P. 1988. "Traditional Economic Models of Fishing Vessels: A Review with Discussion." *Marine Resource Economics* 5 (2): 99–123.

Donaldson, D. 2010. "Railroads of the Raj: Estimating the Impact of Transportation Infrastructure." NBER Working Paper 16487, National Bureau of Economic Research, Cambridge, MA.

Drupp, M. A., M. C. Freeman, B. Groom, and F. Nesje. 2018. "Discounting Disentangled." *American Economic Journal: Economic Policy* 10 (4): 109–34.

Eales, J., and J. E. Wilen. 1986. "An Examination of Fishing Location Choice in the Pink Shrimp Fishery." *Marine Resource Economics* 2 (4): 331–51.

Ekerhovd, N., and D. V. Gordon. 2013. "Catch, Stock Elasticity, and an Implicit Index of Fishing Effort." *Marine Resource Economics* 28 (4): 379–95.

FAO (Food and Agricultural Organization). 2014. "Fishery and Aquaculture Country Profile for the Philippines." Accessed June 1, 2017. http://www.fao.org/fishery/facp/PHL/en.

Filipski, M. J., J. E. Taylor, K. E. Thome, and B. Davis. 2015. "Effects of Treatment Beyond the Treated: A General Equilibrium Impact Evaluation of Lesotho's Cash Grants Program." *Agricultural Economics* 46 (2): 227–43.

Finnoff, D., and J. Tschirhart. 2008. "Linking Dynamic Economic and Ecological General Equilibrium Models." *Resource and Energy Economics* 30 (2): 91–114.

Flaaten, O., and C. E. Schulz. 2010. "Triple Win for Trade in Renewable Resource Goods by Use of Export Taxes." *Ecological Economics* 69 (5): 1076–82.

Gilliland, T. E., J. N. Sanchirico, and J. E. Taylor. 2019. "An Integrated Bioeconomic Local Economy-Wide Assessment of the Environmental Impacts of Poverty Programs." *Proceedings of the National Academy of Sciences* 116 (14): 6737–42.

Gillis, M., C. Shoup, and G. P. Sicat. 2001. *World Development Report 2000/2001: Attacking Poverty*. Washington, DC: World Bank.

Hannesson, R. 1983. "Bioeconomic Production Function in Fisheries: Theoretical and Empirical Analysis." *Canadian Journal of Fisheries and Aquatic Sciences* 40 (7): 968–82.

———. 2000. "Renewable Resources and the Gains from Trade." *Canadian Journal of Economics* 33 (1): 122–32.

Harley, S. J., R. A. Myers, and A. Dunn. 2001. "Is Catch-per-Unit-Effort Proportional to Abundance?" *Canadian Journal of Fisheries and Aquatic Sciences* 58:1760–72.

Hertel, T., ed. 1997. *Global Trade Analysis: Modeling and Applications*. Cambridge: Cambridge University Press.

Homans, F. R., and J. E. Wilen. 2005. "Markets and Rent Dissipation in Regulated Open Access Fisheries." *Journal of Environmental Economics and Management* 49 (2): 381–404.

Jardine, S. L., and J. N. Sanchirico. 2012. "Catch Share Programs in Developing Countries: A Survey of the Literature." *Marine Policy* 36 (6): 1242–54.

Jensen, F., and N. Vestergaard. 2003. "Prices versus Quantities in Fisheries Models." *Land Economics* 79 (3): 415–25.

Johnson, A. E., J. E. Cinner, M. J. Hardt, J. Jacquet, T. R. McClanahan, and J. N. Sanchirico. 2013. "Trends, Current Understanding and Future Research Priorities for Artisanal Coral Reef Fisheries Research." *Fish and Fisheries* 14 (3): 281–92.

Kawarazuka, N., and C. Béné. 2010. "Linking Small-Scale Fisheries and Aquaculture to Household Nutritional Security: An Overview." *Food Security* 2 (4): 343–57.

Kellner, J. B., J. N. Sanchirico, A. Hastings, and P. J. Mumby. 2011. "Optimizing for Multiple Species and Multiple Values: Tradeoffs Inherent in Ecosystem-Based Fisheries Management." *Conservation Letters* 4 (1): 21–30.

Kroetz, K., J. N. Sanchirico, and D. K. Lew. 2015. "Efficiency Costs of Social Objectives in Tradable Permit Programs." *Journal of the Association of Environmental and Resource Economists* 2 (3): 339–66.

Kroetz, K., J. N. Sanchirico, J. Peña-Torres, and D. C. Novoa. 2017. "Evaluation of the Chilean Jack Mackerel ITQ System." *Marine Resource Economics* 32 (2): 217–41.

Lewis, J. P. 1969. "Homogeneous Functions and Euler's Theorem." In *An Introduction to Mathematics: For Students of Economics*, edited by J. P. Lewis, 297–303. London: Palgrave Macmillan UK.

Lindsay, A. R., J. N. Sanchirico, T. E. Gilliland, R. Ambo-Rappe, J. E. Taylor, N. C. Krueck, and P. J. Mumby. 2020. "Evaluating Sustainable Development Policies in Rural Coastal Economies." *Proceedings of the National Academy of Sciences* 117 (52): 33170–76.

Lumley, S. 1997. "The Environment and the Ethics of Discounting: An Empirical Analysis." *Ecological Economics* 20:71–82.

Manning, D. T., J. E. Taylor, and J. E. Wilen. 2018. "General Equilibrium Tragedy of the Commons." *Environmental and Resource Economics* 69 (1): 75–101.

Moseley, W. G. 2001. "African Evidence on the Relation of Poverty, Time Preference and the Environment." *Ecological Economics* 38 (3): 317–26.

Oelofsen, B. W. 1999. "Fisheries Management: The Namibian Approach." *ICES Journal of Marine Science* 56 (6): 999–1004.

Ostrom, E. 1990. *Governing the Commons: The Evolution of Institutions for Collective Action*. Cambridge: Cambridge University Press.

PEP-CBMS (Partnership for Economic Policy Community Based Monitoring Survey). 2011. *The Many Faces of Poverty*. Vol. 2. Manila: PEP-CBMS Network.

Pfeiffer, L., and T. Gratz. 2016. "The Effect of Rights-Based Fisheries Management on Risk Taking and Fishing Safety." *Proceedings of the National Academy of Sciences* 113 (10): 2615–20.

Scott, A. D. 1957. "Optimal Utilization and the Control of Fisheries." In *The Economics of Fisheries: Proceedings of a Round Table Organized by the International Economic Association*, edited by R. Turvey and J. Wiseman, 42–56. Rome: United Nations Food and Agriculture Organization.

Smith, V. L. 1968. "Economics of Production from Natural Resources." *American Economic Review* 58 (3): 409–31.

Taylor, J. E., and M. J. Filipski. 2014. *Beyond Experiments in Development Economics: Local Economy-Wide Impact Evaluation*. Oxford: Oxford University Press.

Thome, K., M. Filipski, J. Kagin, J. E. Taylor, and B. Davis. 2013. "Agricultural Spillover Effects of Cash Transfers: What Does LEWIE Have to Say?" *American Journal of Agricultural Economics* 95 (5): 1338–44.

Wilen, J. E. 2013. "The Challenges of Pro-Poor Fisheries Reform." *Marine Resource Economics* 28 (3): 203–20.

Wilson, J. A. 1990. "Fishing for Knowledge." *Land Economics* 66 (1): 12–29.

World Bank. 1991. "Environmental Assessment Sourcebook." World Bank Technical Paper 139, World Bank, Washington, DC.

———. 2012. *Hidden Harvest: The Global Contribution of Capture Fisheries*. Washington, DC: World Bank.

Worm, B., R. Hilborn, J. K. Baum, T. A. Branch, J. S. Collie, C. Costello, M. J. Fogarty, et al. 2009. "Rebuilding Global Fisheries." *Science* 325 (5940): 578–85.