An integrated bioeconomic local economy-wide assessment of the environmental impacts of poverty programs

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A new generation of poverty programs around the globe provides cash payments to poor and vulnerable households. Studies show that these social cash transfer programs create income and welfare benefits for poor households and the local economies where they live. However, this may come at the cost of damaging local environments if cash payments stimulate food production that conflicts with natural resource conservation. Evaluations of the economic impacts of poverty programs do not account for the welfare consequences of environmental impacts, which are potentially large for poor communities closely tied to natural resources. We use an ex-ante policy simulation tool, a bioeconomic local computable general equilibrium model parameterized with microsurvey data, to analyze the expected welfare consequences of environmental degradation caused by a cash transfer program. For a Philippine fishing community that is a net importer of fish, we show that a government cash transfer program initially increases real incomes for all households. However, increased demand for fish leads to a decline in the local fish stock that reduces program benefits. Household groups experience declines in real income benefits of 2–63%, with fishing households suffering the largest declines. Impacts on local fish stocks depend on the extent to which markets link fishing communities to outside regions through trade. Greater market integration can mitigate the fish stock decline, but this reduces the local income benefits of cash transfers.

cash transfers | natural resources | poverty | bioeconomic models | CGE

Governments and international agencies around the world invest large sums of money in poverty programs in an effort to improve outcomes for households and local economies. Cash transfer programs provide regular payments to poor households and are one of the most widely used poverty alleviation tools (1). Of 142 countries assessed by the World Bank, 70% had unconditional cash transfers, 43% had conditional cash transfers, and the 10 largest cash transfer programs served a combined total of roughly 297 million individuals (2, 3). (Conditions for receiving cash transfers typically include the requirement that children in poor households enroll in schools and local medical clinics, on the theory that improving children's human capital mitigates the intergenerational transmission of poverty.) The scale of spending is also substantial; flagship cash transfer programs in Mexico and the Philippines each have budgets equivalent to ~0.5% of GDP (3, 4).

Cash transfers potentially have both positive and negative impacts. Impact evaluations based on randomized control trials (RCTs) and simulations of expected impacts using local computable general equilibrium (CGE) modeling show that conditional and unconditional programs boost incomes and consumption for payment recipients and promote other positive outcomes, such as increased school enrollment and health checkups (5–9). Impact evaluations also show that indirect benefits reach nonrecipients through local economic spillovers, peer effects, and other factors (8, 10).

Unfortunately, cash transfers also can cause local environmental damage. Latin American and African cash transfer programs led to higher demand for food, resulting in higher land use and local production of environmentally sensitive goods, including by previously landless households (11–14). In the case of Mexico's program, Oportunidades, cash transfers increased local deforestation by stimulating production of land-intensive goods such as meat and dairy products (4). Impacts on local deforestation were larger in areas with lower road density (a proxy for openness to trade), suggesting that markets mediate impacts on the local environment. Recent evidence that cash transfers cause price increases for local natural resources including fish is consistent with these findings (15).

Environmental impacts from cash transfer programs likely have important welfare implications for poor communities in developing countries. Of the approximately 1 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 (16). A metaanalysis of 54 case studies found that 22% of household income in rural areas of developing countries derives from wild or uncultivated natural resources (17). Many natural resources in developing countries are open-access and exist in weak institutional environments; thus, they are vulnerable to overharvesting stimulated by cash-induced demand shocks (18). Work to date has not quantified welfare consequences of the environmental impacts of cash transfers (4, 19).

The contribution of this paper is to estimate how environmental degradation caused by cash transfer programs impacts

Significance

Cash transfer programs assist hundreds of millions of poor individuals in developing countries. However, they create local demand shocks that can cause environmental damage. Degradation of the local environment has consequences for the well-being of local people, but these impacts have not been quantified. We model how cash transfers affect household incomes and market-driven natural resource use. We find that environmental degradation can reduce income benefits of these programs, particularly for individuals whose livelihoods depend directly on natural resources. Our results suggest that cash transfer programs need to be implemented in tandem with environmental policies to achieve welfare gains and mitigate environmental damages that in turn economically harm communities.

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the incomes of different socioeconomic groups. Our findings cast light on the net welfare impacts of cash transfers on households in net-importing resource-dependent local economies. We measure these impacts using an ex-ante policy simulation tool that integrates bioeconomic and local CGE modeling techniques, similar to other integrated frameworks (20–22) but designed to focus on ways in which cash transfers influence the relationship between an economy and its local natural resources. This modeling framework could be applied to other poverty programs or government policies to assess their impacts on natural resources and associated distributional impacts for households. Previous research has shown that cash transfers affect natural resource stock levels in terrestrial systems (4). Using a case study in the Philippines, we show that cash transfers also affect resource stock levels in marine systems, which support the livelihoods of hundreds of millions of people in coastal areas of developing countries (23).

Local CGE models are ex-ante simulation tools that have been used to examine expected policy impacts of cash transfers while accounting for how cash payments ripple through economies (e.g., via labor markets, consumption good markets, and input markets). These models are calibrated and parameterized using microsurvey data (8, 24, 25). They provide a structural complement to reduced-form ex-post impact evaluations based on experiments (e.g., RCTs) or quasi-experimental methods, elucidating mechanisms behind cash transfer impacts including general equilibrium effects (24). We nest a bioeconomic model of a natural resource sector (a fishery) within a local CGE model to account for the environmental impacts of cash transfers over time (*Materials and Methods* and Fig. 1). Bioeconomic models capture the dynamic interaction between a natural resource stock and the economic agents who exploit that resource (26). The integrated model allows us to simulate how environmental impacts of cash transfers feed back into the local economy and affect future economic outcomes. The integration of general equilibrium economic and bioeconomic modeling distinguishes our study from other empirical work on the relationship between the environment and cash transfers or economic growth generally (4, 27). We present impacts over a time horizon of 10 y because natural resource stocks take time to adjust to new levels of harvesting pressure.

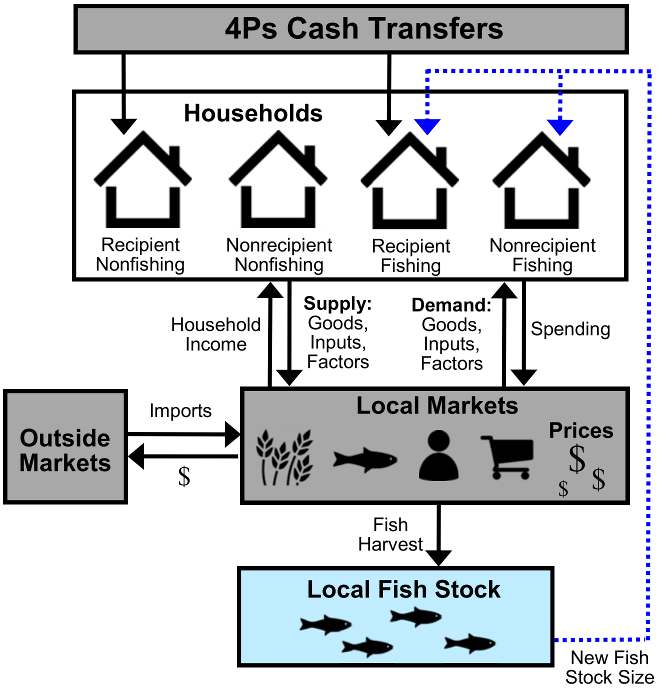

Fig. 1. Conceptual figure of the bioeconomic local CGE modeling framework. Note that some features of the local economy (e.g., nonresidents and tourists) have been left out to highlight features most relevant for assessing impacts of cash transfers. See *SI Appendix* for a full listing of model equations.

We estimate the model parameters econometrically, using data from household, business, and tourist surveys conducted in the municipality of El Nido on the island of Palawan, the Philippines. El Nido is an ideal natural laboratory in which to investigate the feedbacks between environmental outcomes and poverty programs for a number of reasons. First, its poorest residents participate in the Philippine conditional cash transfer program, Pantawid Pamilyang Pilipino Program (4Ps). The 4Ps program seeks to increase consumption and develop human capital by providing cash payments to poor households, conditional on meeting goals related to children's school enrollment, children's health, and the use of maternal health services (28) (for details, see *SI Appendix*). Second, El Nido's local economy is dependent on its natural resource base, which, like many resource extraction settings in developing countries, is subject to open-access extraction and degradation from overharvesting (23). Fishing is a common livelihood in the region, and tourists seek natural amenities. The local fish stock is our environmental outcome variable of interest, given the importance of the fishery for household livelihoods.

The direct income benefits of cash transfers are heterogeneous by design because only poor households receive cash payments. The impacts of environmental damage are also likely to be heterogeneous. Households whose livelihoods depend on resource extraction are impacted directly. Other households are affected indirectly, through market linkages (prices, labor markets, etc.). To highlight the distributional income and environmental consequences of cash transfers, we divide households into four representative household groups based on whether the household received 4Ps payments (recipient/nonrecipient) and whether the household engaged in fishing (fishing/nonfishing).

Other studies show that trade mediates the impacts of local economic shocks by decoupling local demand and local supply (29). We examine three trade scenarios along a market integration continuum (weakly integrated, moderately integrated, and highly integrated) to show how trade can mediate environmental consequences of cash transfers. These scenarios differ by the degree to which fish and agricultural goods imported from outside regions can serve as substitutes for locally produced fish and agricultural goods.

Results

Approximately 40% of El Nido households were part of the 4Ps cash transfer program at the time of our surveys. They received average payments of 240 US dollars per year, equivalent to ∼10% of their total expenditures (*SI Appendix*, Table S1). Using our bioeconomic CGE framework (*Materials and Methods* and Fig. 1), we simulate the impacts of a persistent 50% increase in the size of payments to examine how the local economy and fish stock respond to cash transfers over a 10-y period. This increase is consistent with a recent government decision to increase 4Ps payouts to encourage greater spending on food (30).

Initial Impacts on Local Incomes. The moderately integrated trade scenario best represents El Nido; surveys indicate that imports of fish and agricultural goods are present but limited by transportation infrastructure and other factors, including the availability of quality ice (for details of the trade context, see *Materials and Methods* and *SI Appendix*). In this trade scenario, all resident households benefit immediately from the cash transfer shock (Fig. 2*B*; diamond represents initial impact). Program recipients experience the largest real income gains because of the cash payments they receive. When they spend their cash in the local economy, this creates positive income spillovers for nonrecipients. The largest spillovers accrue to

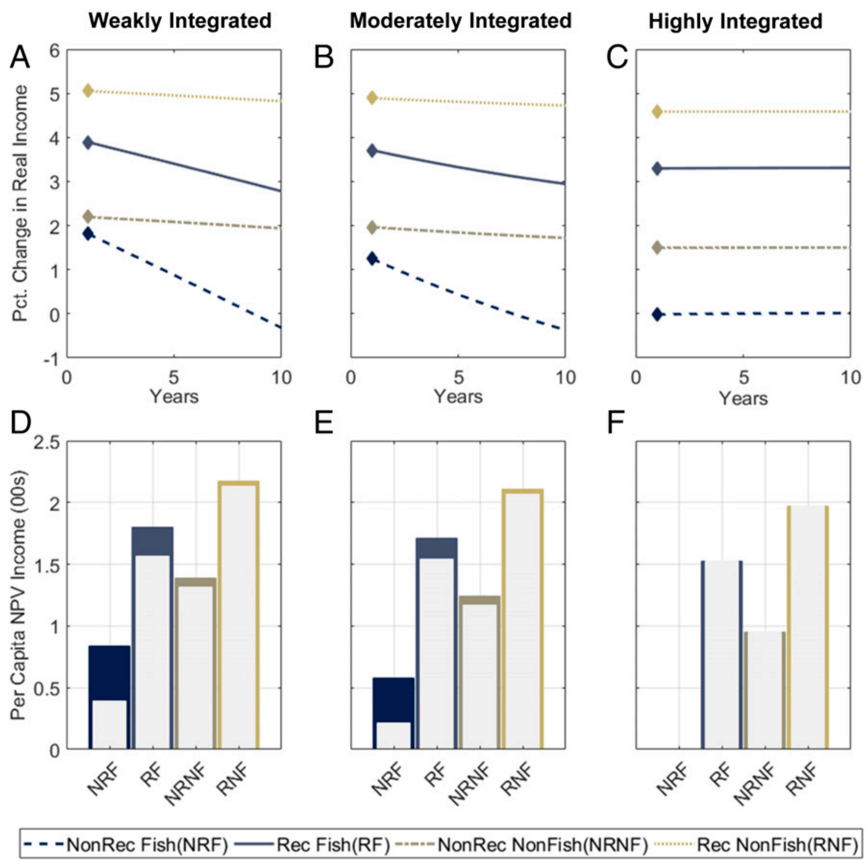

Fig. 2. Impact of cash transfers on household incomes across the three trade scenarios. (*A*–*C*) Impacts on household real incomes. The diamonds represent initial impacts, and percentage changes are relative to baseline levels. (*D*–*F*) The per capita net present value (NPV) of the cash transfer shock over a 10-y period (US dollars) using a discount rate of 0.05. We present NPV results for two different model specifications. The height of the light gray bar represents the NPV using the full bioeconomic local CGE model. The height of the solid colored bar placed behind the light gray bar represents a hypothetical scenario with no environmental degradation (i.e., the fish stock held fixed). The vertical difference between the two bars is the welfare loss that results from environmental degradation caused by cash transfers. The figure columns represent the three trade scenarios. The trade scenario for our field site (moderately integrated) is shown in *B* and *E* and uses Armington trade elasticities of 8 (*SI Appendix*). The weakly and highly integrated scenarios use Armington elasticities of 2 and 200, respectively.

nonrecipient nonfishing households, which own a large share of capital in local businesses patronized by recipients (e.g., retail stores; *SI Appendix*, Table S2). We assessed impacts on nonresidents with businesses in El Nido; however, they do not share in the income gains, inasmuch as their businesses primarily cater to tourists and not to local households.

Impacts on Fishing and Fish Stock over Time. Cash transfers immediately cause higher demand for locally produced and imported fish. The higher demand increases the local price of fish, which in turn raises the economic returns to labor allocated to fishing. This increases labor allocations to fishing relative to other activities and stimulates fish production (Fig. 3; diamond for initial impact and solid line for moderately integrated trade scenario). The increased production reduces the fish stock over time. As the fish stock declines, eventually fish production falls below baseline levels, whereas fish prices remain high. The decline in fish stock over the 10-y period is roughly 3% in the moderately integrated scenario.

Impacts of Fish Stock Decline on Household Welfare. The decline in fish stock leads to decreases in the annual real income of all households over time (Fig. 2*B*), but the impacts are heterogeneous across socioeconomic groups. Nonrecipient fishing households have annual real income in year 10 that is below the baseline level because they are direct users of the natural resource and do not receive cash transfers. Recipient fishing households have annual real income above the baseline because the cash payments they receive outweigh the negative effects of the declining fish stock. The negative impacts of the fish stock decline on nonfishing households are smaller because they are indirect, the result of local market linkages (e.g., via price changes).

We calculate the per capita net present value of the cash transfer shock to measure the dynamic impacts of environmental degradation over time (Fig. 2*E*). We run an additional simulation to highlight potential biases resulting from ignoring environment impacts, artificially fixing the fish stock at the baseline level while keeping all other aspects of the model the same. Running the simulation with the fish stock fixed is akin to extrapolating results from a short-term study (e.g., an RCT using randomized program rollout data) undertaken before the negative impacts of the fish stock decline are felt. Accounting for the fish stock's decline reduces estimated program benefits by 10% for recipient fishing households and by 63% for nonrecipient fishing households. Among nonfishing households, the benefits to recipients and nonrecipients are 2 and 6% lower, respectively. Thus, an evaluation of cash transfer impacts without the bioeconomic model or one carried out before stock declines are measurable would overstate the benefits of cash transfers, especially for direct users of the natural resource. Determining the causal impact of policies in coupled human and natural systems requires methods that avoid such biases (31).

The Role of Trade. Alternative simulations incorporating weakly integrated and highly integrated trade scenarios reveal that the effects of cash transfers depend on the level of integration with outside markets. Imported fish and agricultural goods are less substitutable for local fish and agricultural goods in the weakly integrated scenario than in the moderately integrated scenario. In the highly integrated scenario, imported fish and agricultural goods are near-perfect substitutes for locally produced varieties. Armington functions control the level of substitutability between imports and local goods (32) (*Materials and Methods* and *SI Appendix*).

When the local economy is less integrated with outside markets, local production must increase more to satisfy the demand for tradable goods (fish and agriculture) (Fig. 3, dashed line). This causes greater local economic stimulation and larger initial gains in real incomes (Fig. 2*A*). However, more local production

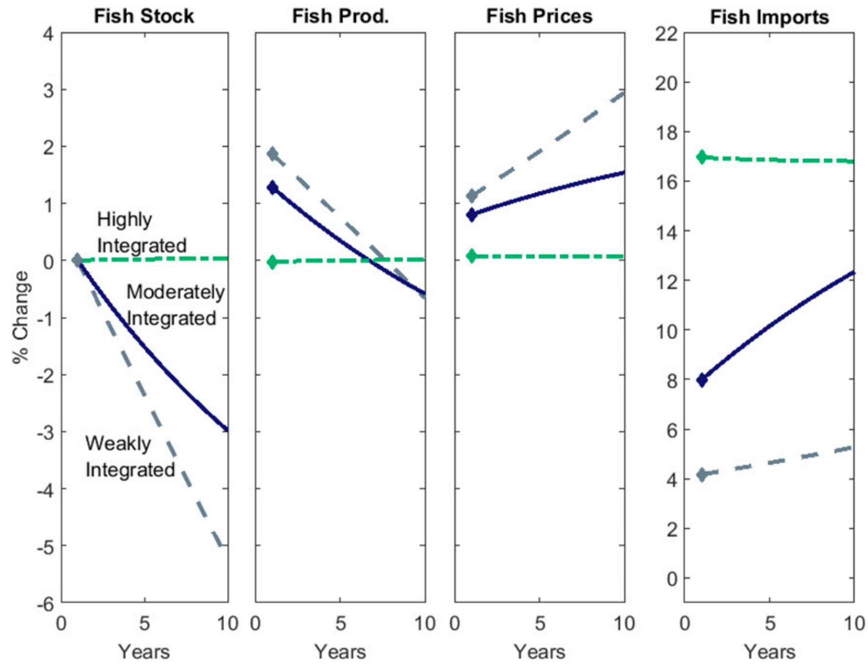

Fig. 3. The impact of cash transfers on the fish stock (first panel), fish production (second panel), fish prices (third panel), and fish imports (fourth panel) across the three trade scenarios. The diamonds represent initial impacts. Percentage changes are relative to baseline levels. The dash-dotted line is the highly integrated case, the solid line is the moderately integrated case, and the long dashed line is the weakly integrated case.

of fish causes a larger decline in the fish stock (Fig. 3, dashed line) and greater associated income losses (Fig. 2*D*).

Alternatively, when the local economy is highly integrated with outside markets, fish demand induced by cash transfers is satisfied entirely by importing fish. This avoids the fish stock decline, higher fish prices, and associated negative welfare consequences by shifting the stimulus elsewhere (Figs. 2*F* and 3, dash-dotted line). However, it results in greater leakages of income from the local economy, reducing the program's stimulus to local real incomes particularly in nonrecipient fishing households that produce tradable fish (Fig. 2*C*).

These results illustrate the tradeoffs inherent in relying on imports to satisfy increased food demands that cash transfer programs create. Greater reliance on imports benefits local natural resource stocks but results in less local economic stimulus. We find that at the end of the 10-y period, the benefits to households of the cash transfer shock are lower when there is more integration with outside markets. The per capita benefits for recipient and nonrecipient fishing households are $4 and $39 lower in the highly integrated scenario than in the weakly integrated scenario. For recipient and nonrecipient nonfishing households, they are $16 and $37 lower (Fig. 2 *D–F*). However, these disparities may change depending on the discount rate and time horizon, inasmuch as the stock is still declining in year 10 (*SI Appendix*, Table S5).

Importing fish mitigates local environmental damage but increases harvesting pressure and potential environmental damage in fish-exporting regions. The 50% increase in cash transfers causes fish imports to increase by 17% in the highly integrated case versus only 4% in the weakly integrated case. Imported fish make up 13% of local fish consumption at baseline. In a fish-exporting economy, it is likely that trade would dampen impacts on resource extraction and reduce local economic stimulus; an increase in local demand could be satisfied by reducing exports. This mediating impact is distinct from the broader impacts that opening up to trade may have on local economies and natural resource extraction. 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 (33). Indeed, research has shown that opening to trade can contribute to higher local resource extraction levels in both terrestrial and marine systems (34, 35). Our analysis focuses on how ex-ante access to trade mediates demand shocks from cash transfers, not on how opening up to trade would alter biological and economic conditions before implementing a cash transfer program.

Discussion

Consistent with other studies on cash transfers, we find that transfers increase initial local incomes for recipient and nonrecipient households (5–9), increase the demand for environmentally sensitive goods (4, 11), increase the price of local natural resources (15), and stimulate production of environmentally sensitive goods in ways mediated by markets (4, 12–14, 36). This lends confidence that our model accurately represents ways in which markets transmit impacts of cash transfers through the local economy.

We contribute to this literature by linking the environmental damage caused by cash transfers back to the local economy and household welfare. The impacts of environmental degradation on household incomes are substantive but heterogeneous, with direct users of the resource harmed most. Environmental damages and their welfare consequences are larger when there is less access to trade, although this result needs to be distinguished from the impacts of opening up to trade (33). Our results should be viewed in light of the institutional context of El Nido's fishery. Because of the open-access nature of the fishery, there are no formal or informal institutions governing the amount of fishing effort or total harvest, and profits from fishing are dissipated (37). Thus, in response to the demand stimulus from cash transfers, fishing effort increases along with catch, leading to a lower fish stock over time. In this context, not atypical of small-scale fisheries in developing countries, there is both an economic and environmental rationale for governments to combine cash transfer programs with resource management policies to mitigate negative environmental impacts. Natural resource management institutions can significantly increase the amount of wealth created by resources and at the same time protect the resource (38, 39). Such institutions might include cooperatives, territorial use rights for fisheries, and individual transferable harvest quotas, among others (40). Institutional arrangements at the regional and national levels may be necessary to legitimize local institutions and prevent exploitation by outside actors (41).

Our ability to simulate the dynamics of the bioeconomic system in El Nido depends on an accurate representation of system constraints and parameter values. Econometric estimation of model parameters builds confidence that our model accurately portrays economic behavior and local market structures. Factor supplies are an important dimension of how local economies respond to economic stimuli. Our base model assumes labor supply is highly elastic due to high levels of unemployment (14%) and underemployment in the region (42). If labor supply is less elastic, there is a more modest initial increase in local production, greater inflation, lower real income gains, and less pressure on the fish stock; however, results do not change appreciably (*SI Appendix*, Table S6). We do not explicitly model changes in leisure demand in response to cash transfers. RCTs find that cash transfers do not discourage work in poor beneficiary households (9, 43). Increased leisure demand would be associated with a lower labor supply elasticity in our model. Our assumption of a constrained capital supply is supported by findings that 4Ps recipient households did not increase their ownership of physical capital as a result of the program (6). If capital were not constrained or if cash transfers relaxed liquidity constraints, this would result in larger increases in local production (8) and potentially larger impacts on the natural resource.

The 10-y time horizon permits the natural resource stock to adjust to new levels of harvesting pressure induced by cash transfers. Adopting a longer timescale would require accounting for program effects not considered in our model. For example, improvements in children's human capital resulting from cash transfers (e.g., through better schooling and nutrition) are expected to facilitate intersectoral occupational mobility at an intergenerational timescale (44), which could influence the scale of local natural resource harvest and other economic activities in the long run.

The representative household framework in our model provides an approximate picture of the disaggregated impacts of cash transfers. The heterogeneity of welfare consequences of environmental degradation may in fact be larger than our results indicate because representative households represent average livelihood strategies for groups (e.g., with regard to capital ownership).

One of the explicit goals of the 4Ps program is to address immediate consumption needs of the poor, but the program has other objectives such as increasing child school enrollment, increasing health checkups for children, and increasing prenatal and postnatal visits. Our estimates of household budget shares reflect existing spending patterns of households participating in the program, and impact evaluations have found that 4Ps increases consumption of cereals and protein-rich food items (6, 15, 45). The exact pattern of how new 4Ps funds would be allocated to different categories of goods is not known. This paper focuses on a conditional cash transfer program, but unconditional cash transfer programs also produce household consumption responses (9, 46), suggesting that our results are relevant for both types of programs. Finally, more nutritious, environmentally intensive food items such as fish and other sources of protein are typically normal goods for poor households. This is a motivation for using cash transfers to induce households to purchase more of these nutritious foods. If, on the other hand, a natural resource were an inferior good (i.e., its demand decreased as incomes rise), higher incomes could in theory decrease the use of the resource.

Our findings relate to large-scale conservation incentive programs. Payments for ecosystem services (PES) and integrated conservation and development programs (ICDP) provide direct or indirect incentives to protect natural resources, frequently in combination with poverty alleviation goals (47, 48). Research suggests that PES and ICDPs suffer from a form of slippage, whereby household income gains from cash or in-kind transfers induce higher local demand for natural resources and local supply responses (47, 49–51). Our results illustrate how this induced demand for natural resources could impact resource stock levels and household welfare in complex ways.

Materials and Methods

Our model of the El Nido local economy is based on local economy-wide impact evaluation models, which are ex-ante simulation tools used to analyze expected general equilibrium effects of policy shocks in local economies (24). Following the literature on agricultural household models, this framework models households engaged in multiple production activities and their interactions with other households through markets for factors, inputs, and consumption goods. In El Nido, we model the six main production activities (tourism, hotels and restaurants, retail stores, fishing, agriculture, and other services). Fisheries products are aggregated into one good given that fishers in El Nido tend to target multiple species simultaneously using many gear types, some of which are unselective (e.g., gillnets). The most commonly caught fish groups in El Nido by weight are tunas, mackerels, squid, and groupers. The factors of production are capital, family labor, hired labor, land, and purchased inputs like fertilizer. Fixed factors are land and capital. A full model description, model code, and necessary data inputs are provided in *SI Appendix*, Tables S12–S16 and Datasets S1 and S2.

We extend the local CGE modeling framework by linking it to a bioeconomic model of a fishery. Household production technologies for all goods take the Cobb–Douglas form, but for fishing, production is also a function of the fish stock size, so that a household value added production function for fishing is

$$QP_t * vash = A\prod_f FD_{f,t}^{\beta_f} * X_t^{\beta_{stock}},$$

where QP_t is quantity produced at time period t, $vash$ is the value added share, $FD_{f,t}$ are factor demands, and X_t is the fish stock size. (Household subscripts are suppressed to simplify notation.) The β parameters are output elasticities, and A is a shift parameter. The time step in the model is 1 y. The artisanal fishery in El Nido is best approximated by an open-access setting with many resource users and no clearly defined property rights. We follow Manning et al. (22) and assume each factor collects a fixed share of the value added attributable to the stock according to that factor's relative contribution to value added. This accounts for the overallocation of factors in open-access and ensures that effort enters until economic profits are driven to zero.

The fish stock level changes over time in response to harvesting pressure. We assume that natural growth of the fish stock is logistic so that

$$X_{t+1} = X_t + \gamma X_t\left(1 - \frac{X_t}{K}\right) - \tau QP_t,$$

where γ is the intrinsic growth rate, K is the carrying capacity for the fish population, and τ translates output into the correct units (kilograms). We assume that a decrease in stock size increases input costs (e.g., petrol) to reflect increasing search costs when fish are less abundant. We define the fishing intermediate demand share ($idsh_t$), which controls fishing input costs, to be a function of the fish stock size as follows:

$$idsh_t = \frac{a}{(X_t)^n}.$$

This scales up cost per unit catch as the stock size decreases. The value of n reflects how quickly costs increase as the fish stock declines, and a is calibrated from cost data. The unknown carrying capacity is calibrated so that the baseline system is in bioeconomic equilibrium, wherein natural growth equals the initial harvest level measured from surveys.

Household demands are derived from constant elasticity of substitution utility functions. For goods that are importable (fish and agricultural goods), imports and domestically produced goods are combined into a composite good according to an Armington function (32). This allows substitutability between imports and domestically produced goods. El Nido does not produce enough food to satisfy local demand, in part due to demand from visiting tourists. El Nido shares similarities with other coastal economies in developing countries. In 2013, tourism was one of the top five sources of export earnings for 83% of developing countries, with a total of 413 billion

US dollars spent by tourists in developing countries (52). A large portion of tourist spending occurs in coastal areas that tourists prefer to visit (53). Coastal population centers, which are growing rapidly in the developing world (54), also would likely be net importers of fish and agricultural goods. Field surveys indicated that commodity exports are largely absent from this economy. The prices of fish and agricultural goods in El Nido depend on local demand, local production, and import levels. Other goods in the local economy are inherently locally produced and consumed (e.g., local services, hotel rooms, and tourist activities) and therefore have prices determined solely by local demand and supply. The model's estimated parameters, chosen parameters, and relevant sensitivity analyses are provided in *SI Appendix*, Economic and Biological Model Parameter Values and Tables S3–S11.

We use this integrated modeling framework to analyze the expected impacts of cash transfers. After the increase in cash transfers, the local economy model solves (instantaneously) for equilibrium prices and quantities (including fish harvest) conditional on a fixed fish stock level in year $t = 1$. The level of fish harvest is used to calculate the stock level size in year $t = 2$. The CGE model in year $t = 2$ then solves for a new set of equilibrium prices and quantities conditional on the new fish stock level, which allows the local economy to adjust to the new productivity level in the fishery resulting from the change in fish stock size.

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