Oil Extraction and Indigenous Livelihoods in the Northern Ecuadorian Amazon

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Introduction

In the Amazon Basin and other parts of the world, the large-scale extraction of mineral resources and fossil fuels is increasingly penetrating into isolated and biodiverse regions inhabited by indigenous peoples. This process is of significant global concern due to the dramatic regional-scale economic and environmental changes that can result from these activities, along with the perceived vulnerability of indigenous peoples, their livelihoods and their lands (O'Faircheallaigh, 2013). These issues are particularly evident in the Western Amazon where areas of oil and gas extraction and exploration overlap with some of the world's highest concentrations of biodiversity as well as the territories of indigenous peoples living in isolation (Finer et al., 2008). These concerns are exemplified by the attention surrounding the ongoing legal action by residents of the Ecuadorian Amazon against Texaco/Chevron, which was responsible for widespread oil pollution (Kimmerling, 1991; Valdivia, 2007).

However, viewed locally, these issues are much more complex. In response to criticism of past practices and the growing influence of environmental and indigenous movements, corporate and state policies on resource extraction have become more favorable to indigenous peoples over time (O'Faircheallaigh, 2013). Given the employment opportunities and aid distribution that can result, not all indigenous groups are opposed to the expansion of extractive activities in their territories (Valdivia, 2007). Nonetheless, the social and environmental history of the extractive industries in the Amazon Basin is an ugly one (Bebbington & Bury, 2013), and indigenous peoples remain at an enormous disadvantage when interacting with oil companies and allied state bodies (Swing et al., 2012).

These concerns lead to an important question: What can empirical research tell us about the consequences of large-scale resource extraction for the livelihoods of indigenous peoples? A relatively small number of studies have previously addressed this question, primarily using small-scale, qualitative approaches (e.g., Bebbington & Bury, 2013). These studies suggest mixed effects on social and economic outcomes and negative effects on environmental outcomes, as described in detail below. However, few if any studies have been able to draw robust, regional-scale conclusions about these processes, in part reflecting the absence of large-sample, longitudinal datasets.

To address this lacuna, we use data from a unique longitudinal survey from the Ecuadorian Amazon covering 32 indigenous communities, 484 baseline households, an 11-year period, five ethnicities, and a wide range of exposures to oil exploration and extraction. Drawing on a multilevel, multivariate analytical approach, we use these data to investigate the effects of community-level exposure to oil activities on various dimensions of indigenous livelihoods, including participation in off-farm employment, agriculture, hunting and fishing, as well as ownership of consumer goods. The results of this analysis suggest that exposure to oil extraction has mixed effects on indigenous livelihoods and has contributed to a shift away from traditional livelihood activities. These findings are consistent with previous studies in other settings, but challenge the common narrative that the consequences of extractive activities for indigenous peoples are wholly negative.

Large-scale resource extraction and indigenous peoples

Driven by favorable state policies, rising commodity prices, new technologies of extraction, and the depletion of traditional supplies, the extraction of mineral resources and fossil fuels by national and transnational companies has expanded globally into isolated areas inhabited by indigenous peoples (O'Faircheallaigh, 2013). Many of these areas are also important reservoirs of biodiversity (Naughton-Treves et al., 2005). In most cases, the material consequences of large-scale resource extraction include the construction of transportation infrastructure such as roads, the installation of extraction infrastructure such as mines and wells, the removal of natural vegetation and/or soil, and the introduction of toxic materials such as petroleum and mine tailings (O'Rourke & Connolly, 2003; Bebbington & Bury, 2013). To construct, operate and maintain this infrastructure, a predominately non-local staff must also be employed, fed, and housed.

When these activities take place in isolated indigenous territories, they commonly affect populations whose livelihoods are directly dependent on the natural environment, who interact primarily through communal tenure systems and non-market forms of exchange, and who have limited access to external markets, services and resources (Godoy et al., 2005). As such, extractive activities can potentially represent a major transformation of the social, economic and environmental context, including the introduction of private land tenure and the expansion of incipient local market economies (O'Faircheallaigh, 1998). Compounding these changes, companies may offer access to employment, cash payments, or health and transportation services to indigenous communities in order to facilitate their work and/or to comply with legal or internal mandates for "corporate social responsibility" (Hilson, 2012; O'Faircheallaigh, 2013), although the timeframe of these benefits may be short. In other cases, indigenous communities may simply be dispossessed of their traditional lands and resources with little recourse, reflecting their marginal position within national political economies as well as alliances between state bodies and extractive industries (O'Rourke & Connolly, 2003). In either of these cases, protests, displacement, violence, and intra-community feuds can result, potentially halting or curtailing the extractive activity (Haley, 2004; Lu, 2012; Sawyer, 2004).

Building on a definition of livelihoods as "the capabilities, assets and activities required for a means of living" (Chambers & Conway, 1992), the background above suggests four pathways by which large-scale resource extraction could affect indigenous livelihoods. Extractive activities could lead to a loss of access to natural capital (land, water and forests), undermining traditional livelihood activities such as wild resource harvesting and small-scale agriculture. However, new employment opportunities and access to physical capital (tools, inputs and infrastructure) could lead to livelihood diversification, increasing cash incomes and access to consumer goods. Meanwhile, human capital (health and knowledge) could be undermined by exposure to toxins and new diseases or, alternatively, improved by access to education, information and health services from the outside world. Similarly, social capital (trust and social relationships) could suffer from the introduction of inequality and market-based forms of exchange, or could potentially strengthen due to the need to organize engendered by the changing context. Overall, this framework suggests the possibility of both positive and negative effects on indigenous livelihoods, with the legal and institutional context likely to play a central role.

Consistent with the framework described above, previous small-scale studies of mining in the Andes and oil extraction in the Amazon reveal both mixed and negative effects of resource extraction on indigenous livelihoods. Studies of the Yanacocha gold mine in Cajamarca, Peru, found that local rural communities experienced improvements in economic status and access to education and health services, but declines in water quality, access to land, and intra-community social capital (Bebbington & Bury, 2009; Bury, 2004). More negatively, studies in the Achuar territories of the Corrientes River region of the Peruvian Amazon reveal that oil extraction led to widespread water pollution and the depletion of wild resources by outsiders, but, following protests and activism, some degree of increased access to wage employment and health services (Bebbington & Scurrah 2013; Orta-Martinez & Finer, 2010). Meanwhile, Hindery (2013) found that community development projects planned for indigenous communities affected by the Don Mario mine in remote eastern Bolivia were only partly successful, and that mine-driven road improvements led to significant new pressure on natural resources by outsiders. Similar stories of mixed and negative outcomes are available from indigenous communities across the developing world (Gardner et al., 2012; Gilberthorpe & Banks, 2012; Lu, 2012; Van Alstine & Afionis 2013).

These studies provide important preliminary evidence that large-scale resource extraction can potentially have positive benefits for indigenous communities but that the overall effects are more often negative. However, the strength of the findings cited above is limited by the exclusive use of small-scale, case-study designs, typically including one or a few communities and lacking data from multiple time periods or unaffected communities. With the goal of expanding the range of methods used in this type of research, we demonstrate below how structured household surveys and multivariate statistics can also be used to address these issues. The results provide additional evidence that the effects of extraction on indigenous livelihoods are not exclusively negative, and, taken together with studies cited above, challenge common assumptions about these processes.

Study context

We investigate these issues in the context of the Northern Ecuadorian Amazon (NEA), an epicenter of indigenous cultural diversity, tropical biodiversity, and oil exploration and extraction. The NEA (Figure 1) overlaps the center of Amazonian species richness for amphibians, birds, mammals and vascular plants, marking it a globally important region for biodiversity conservation (Finer et al., 2008). [Figure 1 here.] This region is also home of the Cofán, Secoya, Waorani peoples, multiple Kichwa-speaking populations, Shuar in-migrants from the southern Ecuadorian Amazon, and a few smaller indigenous groups, for a total indigenous population of more than 60,000 in the 2010 population census (INEC, 2014).

Prior to the 1970s, these indigenous groups experienced some contact with the outside world but lived in relative isolation on lands almost entirely covered in forests and wetlands. Beginning with the discovery of large oil deposits near Lago Agrio in 1967, the region has been transformed by oil exploration and extraction, first by Texaco and Gulf and subsequently by other transnational companies as well as the state oil company, Petroecuador (Sabin, 1998). These activities have directly affected indigenous peoples through the extensive construction of oil and transportation infrastructure, subsequent oil pollution, development projects, and new markets for low-skilled labor (Bremner, 2013). These activities, together with allied state policies, have also indirectly affected indigenous peoples by facilitating in-migration from the Andes, agricultural colonization, and, increasingly, urbanization of the region (Bilsborrow et al., 2004). The result is that indigenous peoples have largely been displaced from the main area of colonization between Coca and Lago Agrio, and now cluster on the periphery of this zone as well as along rivers accessed via motorized canoe (Figure 1).

The Cofán, Secoya, Waorani, Kichwa, and in-migrant Shuar have responded to these changes in a variety of ways, including through participation in new markets for labor, crops, tourism and forest products (Lu & Bilsborrow, 2011). However many households continue to live in landscapes dominated by forest and to rely on traditional activities such as hunting, fishing and swidden agriculture, particularly the Cofán and Waorani (Gray et al., 2008; Gray et al., in press). All of these groups have also responded with political organizing and activism that has resulted in increased visibility and the legal recognition of their territories, though on a small fraction of their traditional lands and without subsurface rights. Oil exploration and extraction continue in the region, but under new policies of "corporate social responsibility" that include negotiations with regional, ethnicity-based federations as well as directly with local communities (Haley, 2004; Valdivia, 2007). Corporate practices of road construction and waste handling have also improved, reducing but not removing environmental impacts (Baynard et al., 2013; Suarez et al., 2013). International and national political opposition to the expansion of oil extraction also continues, but the Ecuadorian government has responded most recently by opening new areas to extraction, including those inhabited by isolated Waorani communities and in Yasuní National Park (Pappalardo et al., 2013).

The case of three Waorani communities in this region described by Lu (2012) is illustrative of these dynamics. The communities of Huentaro and Quehureiri-ono are located in a remote area in the Waorani ethnic reserve but came into contact with the oil company Oryx in 1997 while it was conducting seismic testing. Consistent with an agreement signed with the Waorani federation, Oryx provided food drops by helicopter during this period and also hired community members, primarily for manual labor. After the seismic testing was concluded and adequate oil reserves were not found, Oryx exited the area and community members returned to their previous reliance on traditional livelihood activities. However, the perception that resources from Oryx accrued disproportionately to one group of families led to intra-community conflicts and, consistent with high levels of spatial mobility by this ethnic group, the departure of many households to other communities. Muliple households relocated near an existing oil road to found another community, Gareno. This group benefited from infrastructure, aid and transportation provided by the oil company Perenco until its departure in 2009. Operations were then taken over by Petroecuador, which has continued to provide transportation but no other services. Relative to residents in Huentaro and Quehureiri-ono, Gareno residents are more reliant on external markets and have less access to wild resources, but both groups report being generally satisfied with their current place of residence.

As this background makes clear, oil extraction in the NEA has resulted in a dramatic transformation of the regional context for indigenous peoples. However, what remains unclear is how these changes have affected indigenous livelihoods at household and community scales across the region. Has exposure to oil employment, contamination, and development projects undermined traditional livelihood activities such as hunting and fishing across the region? Or have these new opportunities improved well-being in indigenous communities? Divided opinion among the regional indigenous federations as to how to interact with oil companies suggests that both outcomes are possible (Valdivia, 2007), and answers are needed as oil extraction proceeds into new indigenous territories.

Data collection

To address these issues, we draw on unique longitudinal household survey data collected in 2001 and 2012 in 32 indigenous communities of the NEA (Fig. 1). In 2001, a judgment sample of 36 communities was selected to include all five ethnicities and to span the regional spectrum of community size, accessibility and exposure to the outside world. Among these, 32 communities were selected for follow-up in 2012 as described below. Following a household listing in each community, 22 households were sampled for participation, either randomly or to include all households in smaller communities. In each sample household, structured interviews were separately conducted with both the male and female heads of household (i.e., one man and woman per household) for approximately one hour in order to collect a wide variety of information on household characteristics and activities, including on household composition and assets, perceptions of environmental contamination, and participation in agriculture, wild product harvesting, off-farm employment and other activities. In the case of single-headed households or the prolonged absence of the male/female head, both questionnaires were administered to the available household member. In the 32 longitudinal communities, 484 households completed a male interview, 489 households a female interview, and 476 both interviews. Community-level data was also collected through the use of GPS as well as through structured interviews with community leaders focusing on community institutions, infrastructure and exposure to outside actors. To collect these data, a survey team of six Ecuadorian interviewers spent approximately five days in each community. Interviews were conducted primarily in Spanish and only rarely required the assistance of a local translator.

The 2012 follow-up survey targeted households in the study communities who completed a female interview in 2001 and thus provided a household roster. The first priority for follow-up was the 2001 female head and her 2012 household, followed, in the case of the female head's absence or death, by the 2001 male head, and finally by the oldest child resident in 2001. Three communities from the 2001 survey were excluded for logistical reasons, and in another community all baseline households had departed, leaving 32 communities for the longitudinal sample. Among the 489 targeted households, 401 completed a male interview, 399 completed both interviews, and 75 had permanently left the community. Split-off households, where a 2001 household member was now male or female head, were also included. Among these split-offs, 200 completed a male interview, all of whom also completed a female interview, for a total of 599 households with complete male and female interviews in 2012. A questionnaire similar to the baseline was used, updated to include questions about changes experienced since 2001.

Analysis

To describe indigenous livelihoods and oil activities in the NEA, we first use these data to conduct descriptive analyses of community-level interaction with oil companies (Table 1) and of various dimensions of household livelihood strategies (Table 2). [Tables 1 and 2 here.] All households that completed a male interview in either year were included in this analysis. Because some communities include members of more than one indigenous ethnicity as well as a small number of non-indigenous (mestizo) residents, we classify households by the ethnicity of the economic head (who is usually male). To compare household-level values across time, we conduct Pearson's chi-squared tests for dichotomous variables and Wald tests for continuous variables, all of which are adjusted for clustering at the community level. To account for the possibility of non-random selection into our multi-year sample, all descriptive and multivariate analyses were repeated using the subset of data from panel households who were interviewed twice, with results very similar to those presented here.

To measure the effects of oil activities on indigenous livelihoods, we combine the data from both survey years from households that completed both male and female interviews (n = 1075 household-years). We then use these data in regression analyses incorporating both random and fixed effects (Woolridge, 2012). We first estimate the following random effects model:

$$y_{ijt} = y_{000} + \beta x_{ijt} + \delta w_{jt} + \alpha_j + u_{ij} + e_{ijt}$$

where y_{ijt} is the outcome for household *i* in community *j* in year *t*, y_{000} is the common intercept, β is a vector of household-level coefficients, x_{ijt} is a vector of household-level predictors, δ is a vector of community-level coefficients including exposure to oil activities, w_{jt} is a vector of community-level predictors, α_j is the community-level random effect, u_{ij} is the household-level random effect, and e_{ijt} is the residual error term. For censored outcomes (with a large proportion of zeroes) we use a two-step procedure, first using logistic regression to model the dichotomous measure of participation, and then using linear regression to model the non-zero continuous outcomes.

This model tests whether oil activities are associated with livelihood outcomes while accounting for potential confounders as well as clustering at both household and community scales. By exploiting both spatial and temporal variation in exposure to oil activities, this approach takes maximal advantage of our sample size but does not fully account for the possibility of non-random implementation of oil company activities in communities with particular livelihood profiles. To account for this possibility, we re-estimate the model above, replacing the community-level random effect with fixed effects (i.e., a set of indicator variables). This approach allows each community to have a baseline level of participation in each livelihood strategy, and identifies the effect of oil activities using only temporal variation within communities. However, the cost of the latter approach is a loss of statistical power. Given our modest sample size at the community level, we present the former approach as our primary specification and the latter approach as a supplement.

The selection of both outcomes and predictors for this analysis was informed by the livelihoods framework (Chambers & Conway, 1992; Ellis, 2000). In this framework, each household is viewed as the manager of a portfolio of livelihood activities that build upon various assets or capitals, including natural, human, social, and physical capitals. These decisions are made in a changing local and regional context, and contribute to the level of household well-being. Given the many potential dimensions of livelihoods and the limitations of our data, we do not attempt to measure all aspects of indigenous livelihoods, but instead define five key outcomes capturing participation in off-farm employment, hunting, fishing and small-scale agriculture, as well as ownership of consumer goods. These outcomes include two traditional livelihood activities that are not strongly connected to the market (hunting and fishing), one activity that is for both subsistence and market purposes (agriculture), one activity that is market-based (off-farm employment), and one measure of material well-being (consumer wealth).

As displayed in Table 2, participation in off-farm employment (OFE) was measured as total household income in 2012 US dollars from wage employment in the previous 12 months, including employment with oil companies as well as other employers. Participation in hunting was measured by the weight of game captured in the previous hunt, set to zero for households that did not hunt in the previous 12 months. Both of these outcomes have a large proportion of zero values, and are thus modelled using the two-step approach described above. Participation in fishing was similarly measured by the weight of fish captured in the previous outing, set to zero for the small number of households that did not fish in the previous 12 months. Participation in agriculture was measured by the area cleared for agriculture in the previous three years. In the system of swidden agriculture practiced in the study communities (Gray et al., 2008), the area cleared in the past three years is a large fraction of the total agricultural area (Table 2) and excludes older stands of perennials such as coffee, which may predate oil exposure. The positive values of these four outcomes (OFE, hunting, fishing, and agriculture) are all significantly left-skewed, so have been transformed as $\ln(y+1)$ for the analysis.

Finally, for the fifth outcome we constructed a multivariate index of consumer wealth. To do so, we first defined a set of 28 indicator variables for ownership of various consumer goods (e.g., a cellular phone) and housing characteristics (e.g., an improved floor) along with one continuous variable (number of rooms in the dwelling). To combine these measures into a single continuous index, we used polychoric principle component analysis on the joint 2001-2012 dataset and took the first principle component (Kolenikov & Angeles, 2009). Consistent with a measure of wealth, this analysis produces positive weights for each asset and improved housing characteristic, with the sole exception being ownership of a rifle (which is common among poor and isolated households). This continuous value was then standardized to range from zero to ten to produce our index. Data on consumer wealth is missing for 22 household-years, resulting in a smaller sample size for the analysis of this outcome (n = 1053).

As predictors in this analysis, we include two alternate measures of exposure to oil activities as well as a large set of control variables (Table 3). Exposure to oil is measured at the community level, first by the number of employees hired by oil companies from the community in the previous 12 months, and second by the number of development programs implemented by oil companies in the previous ten years. These measures are correlated with each other ($p = 0.07$) and presumably with other unmeasured dimensions of exposure to oil, such as environmental contamination and the availability of transportation in oil company vehicles. Thus we conceptualize these measures as partly-correlated dimensions of the overall community exposure to oil, and, consistent with this view, we test them in separate versions of the model described above.

In addition to one measure of oil exposure, we also include several control variables in each model (Table 3). [Table 3 here.] Household-level controls include the number of household members and the ethnicity, age, gender, education, Spanish language ability, and place of birth of the household economic head. Community-level controls include the population size of the community and travel time to the nearest city. Selection of these controls builds on multiple previous studies of rural livelihoods in the NEA (Barbieri et al., 2005; Barbieri et al., 2013; Bremner, 2013; Gray et al., 2008), as well as on the livelihoods framework (Chambers & Conway, 1992; Ellis, 2000).

Results

Descriptive results on community interaction with oil companies are shown in Table 1. Overall, 19 of 32 communities in both years had at least one member employed by oil companies in the previous 12 months, with 12 communities switching over time from having to not having or vice versa. A smaller and declining number of communities, 13 in 2001 and 6 in 2012, were also exposed to oil extraction through the receipt of aid and assistance programs in the previous ten years, with provision of health services the most common form of assistance. Reflecting a high and increasing level of activity by government, private and non-profit actors in this region, these programs represented only 17% and 11% of all aid programs in 2001 and 2012, respectively. While all five ethnicities were exposed to oil activities, exposure was very low for the Cofán and Secoya. The Waorani had more contact despite the remote location of their communities (Figure 1), reflecting the status of their territory as a new oil exploration frontier (Lu 2012; Suarez et al., 2013).

Descriptive results on household livelihoods are displayed in Table 2, including off-farm employment (OFE), agriculture, wild product harvesting, assets, health and perceptions of environmental contamination. Regarding OFE, approximately half of all households participated in both years, with one half to one third of those finding employment with oil companies. Wages and income were comparable for the two sets of households and rose over time. Employment with oil companies was particularly common among the Waorani, consistent with their high exposure to oil companies. Nearly all households of all ethnicities participated in small-scale agriculture, with most also clearing land in the previous three years, though the areas cultivated and cleared both declined slightly over time. Participation in hunting and fishing were similarly high but declining over time, though harvests per outing did not significantly decline. Over the same time period as this apparent transition away from traditional livelihood strategies, household consumer assets and self-reported health both significantly improved, suggesting improved overall well-being. However, households also commonly perceived their water, air and soil to be contaminated by oil companies, though we do not have access to field measurements that could confirm these perceptions. Taken together, these results paint a picture of slowly declining participation in traditional livelihood strategies at a time of improving material well-being, raising the question of whether exposure to oil activities has contributed to these trends.

The results of the multivariate analyses of livelihoods outcomes are displayed in Table 4 (for censored outcomes) and Table 5 (for non-censored outcomes). [Tables 4 and 5 here.] Unstandardized coefficients are presented for linear models, and odds ratios are presented for first-step logit models; the latter can be interpreted as the multiplicative effect of a one unit increase in the predictor on the odds of participation. Overall these models reveal positive effects of oil exposure on OFE, hunting harvests and assets, with no effects on agriculture and negative effects on fishing.

Beginning with the two-step models in Table 4, the odds of household participation in OFE increased 2% ($p = 0.015$) with each employee hired by oil companies and 14% ($p = 0.061$) with each oil assistance program. The former result remains marginally significant ($p = 0.091$) once community fixed effects are added. Income from OFE also significantly increased with oil company assistance programs ($p = 0.003$). Using the untransformed units and the random effects specification, one additional oil program would increase OFE income for participating households to $3,844 from the 2012 mean value of $3,471. This result remains significant when controlling for community fixed effects, but the effects of number of oil employees in the community on OFE income of those working were non-significant in both specifications. Regarding hunting, oil exposure did not have significant effects on hunting participation, with the partial exception of a small, marginally-significant negative effect of oil employees in the fixed effects model ($p = 0.092$). Similarly oil assistance did not have any significant effects on hunting harvests, but harvests did increase with oil employees under both the random effects ($p = 0.002$) and fixed effects specifications ($p = 0.041$). Using the untransformed units and the random effects specification, one additional oil employee would slightly increase hunting harvests to 12.3 kg from the 2012 mean value of 12.1 kg.

Continuing with the single-step models in Table 5, consumer assets were not significantly influenced by the number of oil company employees but increased significantly with oil assistance programs in both random effects ($p = 0.011$) and fixed effects ($p = 0.057$) specifications. In both cases the addition of one oil assistance program raised assets by 0.1 units on a 10 point scale. The effects of oil exposure on agricultural clearing were not significant in all specifications. Finally, fishing harvests *decreased* slightly with each additional oil company employee in both random effects ($p = 0.078$) and fixed effects ($p = 0.019$) specifications. Using the untransformed units and the random effects specification, each oil employee reduced fishing harvests slightly to 5.50 kg from the 2012 mean value of 5.52 kg. The effects of oil assistance programs on fishing were non-significant.

The control variables were jointly significant in all 14 models and had effects that were consistent with expectations, lending credence to the findings above. Assets and all livelihood activities increased with household size and decreased with female headship. Households with heads that were older, born locally or did not speak Spanish were generally more likely to participate in traditional livelihood activities and less likely to participate in non-traditional activities, and the opposite was true of heads with at least a primary education. Controlling for these characteristics, Waorani households were still more likely to participate in both OFE and hunting. At the community level, traditional activities tended to decline with population size and increase with remoteness, and the opposite was true of non-traditional activities and assets. Finally, participation in hunting, hunting harvests and agricultural clearing decreased over time net of any oil and control effects, whereas OFE income and assets increased, suggesting a trend of modernization that is not fully explained by oil exposure or household characteristics.

Discussion

Using a unique longitudinal dataset and a multivariate approach, we show that exposure to oil exploration and extraction is associated with mixed livelihood outcomes in indigenous communities of the Ecuadorian Amazon. Overall, exposure to oil is linked to increased participation and income from off-farm employment (OFE), increased ownership of consumer assets, increased hunting harvests, and decreased fishing harvests, and is not associated with agricultural clearing. The effects on OFE and fishing are consistent with expectations and with the observed overall trend away from traditional livelihood strategies. Oil companies hire community members directly and also generate additional OFE indirectly through aid programs and new business opportunities, creating opportunities to accumulate consumer goods. Consequent reductions in available labor and increases in wealth likely undermine participation in fishing, though water contamination by oil activities may also play a role. Unlike these changes, the positive effect on hunting harvests was unexpected but is consistent with the observations of Suarez et al. (2013) that indigenous peoples in the NEA take advantage of oil-linked improvements in accessibility to participate in growing markets for bushmeat.

These results contain important lessons regarding the conventional narrative of resource extraction in indigenous territories, the research methods used in this field and the implications of expanded oil production for the NEA. Informed by the ugly history of past practices, the conventional narrative is that resource extraction in indigenous territories undermines autonomy, household well-being, and traditional livelihoods and culture. While we cannot test for longer-term effects, we test for short-term effects on livelihood practices and well-being, and find results that are only partly consistent with this narrative. There is indeed some shift away from traditional livelihood activities, but at the same time benefits are accruing to households through increased access to wage employment and consumer goods. We also observe that community exposure to oil extraction is not unidimensional, with assistance programs having notably more positive effects on assets and income. Though these results are inconsistent with the conventional narrative, they are consistent with several previous studies cited above which have also observed mixed effects of resource extraction on indigenous livelihoods and well-being. Researchers and policy-makers thus need to recognize the potential *for both costs and benefits* for indigenous communities as a consequence of resource extraction, with the balance of the two highly dependent on the local context and often negative.

The results also contain an important message about the consequences of oil production in the NEA, which is now expanding into the extraordinarily biodiverse Yasuní National Park and the territories of indigenous peoples seeking to live in isolation (Pappalardo et al., 2013). Given the significant changes that we observe in indigenous livelihoods following oil extraction, our results reinforce the need to give indigenous communities greater control over extractive activities that occur in their territories, as well as greater access to information on the potential consequences of these activities. Not all indigenous communities would choose to exclude extractive activities from their territories given the potential benefits, but those who would should have the right to do so. In addition, the local and global environmental consequences of oil extraction in the NEA, including carbon emissions, water pollution and road construction (Finer et al., 2008), have not been specifically addressed here, but also provide strong motivation to more carefully regulate these activities.

Finally, this study also provides a detailed illustration of how survey and statistical methods can be used to investigate changing indigenous livelihoods, complementing previous research which has largely used small-scale, case study approaches. The approach presented here allows the measurement of *regional-scale* trends as well as the *quantification* of multi-scale influences on livelihood outcomes, complementing the thick description and attention to context that comes from smaller-scale approaches. Broader use of quantitative methods could increase the power and visibility of research on the indigenous peoples of the Amazon and elsewhere, as previously demonstrated by Godoy et al. (2005), Rudel et al. (2013) and others. Nevertheless, we consider this to be a preliminary rather than conclusive quantitative analysis of this topic, and our approach would benefit from multiple extensions. These include the collection of detailed measures of social capital, the collection of biological measures of health and toxic exposures, integration with ethnographic methods, and expansion to a larger sample of communities as well as a longer time period.

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Table 1. Community-level measures of exposure to oil companies by ethnicity and year.

Measure	Full Sample		Kichwa		Shuar		Waorani		Cofán		Secoya	
	2001	2012	2001	2012	2001	2012	2001	2012	2001	2012	2001	2012
Employment with oil companies												
Number of communities exposed	19	19	8	8	6	5	3	5	1	0	1	1
Number of community members employed	204	239	122	105	17	34	53	99	11	0	1	1
Assistance from oil companies												
Number of communities exposed	13	6	5	2	3	2	4	1	1	0	0	1
Received health assistance	5	3	2	1	1	1	2	0	1	0	0	1
Received reforestation assistance	1	2	0	2	0	0	1	0	0	0	0	0
Received perennial crop assistance	0	3	0	2	0	1	0	0	0	0	0	0
Received other assistance	11	4	3	2	3	1	4	1	1	0	0	0
Total number of assistance programs	28	18	6	13	6	3	13	1	3	0	0	1
Total number of programs from any source	168	170	83	91	35	26	28	22	14	14	8	17
Total number of communities	32		14		8		5		3		2	

Table 2. Household-level measures of livelihoods, perceptions and assets by ethnicity and year, with tests for changes over time.

Measure	Full Sample		Kichwa		Shuar		Waorani		Cofán		Secoya		Mestizo	
	2001	2012	2001	2012	2001	2012	2001	2012	2001	2012	2001	2012	2001	2012
Off-farm employment														
Employed off-farm in past year (0/1)	0.58	0.51	0.46	0.46	0.57	0.63	0.94	0.72 +	0.61	0.37	0.59	0.45	0.83	0.63
Person-months worked per yr.	9.09	7.45 *	8.33	7.98	5.76	6.69	13.08	6.69 **	11.15	6.69 +	7.28	6.02	8.33	8.40
Average daily wage (2012$/day)	19.1	25.3 **	15.0	23.6 ***	28.2	24.4	22.3	25.9	12.7	23.2 **	16.0	41.7	17.6	27.2 +
Yearly earnings (2012$/year)	1777	3471 ***	1459	3508 ***	1948	3657 +	2747	3160	1238	2448 **	975	3674	1502	3873 **
Employed by oil co. in past year (0/1)	0.26	0.17 *	0.17	0.10	0.36	0.31	0.52	0.56	0.16	0.02	0.24	0.03	0.28	0.22
Person-months worked for oil co. per yr.	4.72	6.12 **	5.10	6.31	2.91	4.64 +	7.00	6.55	2.43	4.00 +	3.38	2.00	3.60	9.11 **
Average daily wage from oil co. (2012$/day)	22.1	23.0	18.8	21.3	28.8	22.6 +	19.5	25.2	24.4	20.0	19.0	18.5	20.4	24.2
Yearly earnings from oil co. (2012$/year)	1644	2589 ***	1483	2258 +	1478	2407	2222	2892	1128	1600	855	740	1960	3800
Agricultural land use														
Land in agriculture (hectares)	2.88	2.39 +	3.46	2.63 *	3.52	2.04 **	1.38	2.20 **	1.98	1.78	1.55	2.85	2.12	1.64
Household cleared land in past 3 years (0/1)	0.88	0.82 +	0.92	0.84 +	0.80	0.77	0.98	0.91	0.77	0.72	0.74	0.79	0.89	0.76
Area cleared in past 3 years (hectares)	1.98	1.46 **	2.20	1.55 *	2.08	1.20 *	1.26	1.82 *	1.16	0.94	2.62	1.80 +	1.88	1.02 +
Wild product harvesting														
Hunted in past month (0/1)	0.72	0.47 ***	0.69	0.42 ***	0.62	0.45 +	0.88	0.65 +	0.80	0.72	0.82	0.50 **	0.67	0.44 *
Hunted in past year (0/1)	0.88	0.65 ***	0.84	0.59 ***	0.84	0.64 **	0.98	0.87 *	0.93	0.87	1.00	0.76	0.83	0.59
Game caught on the most recent hunt (kg)	14.4	12.1	12.8	9.7	8.5	9.2	19.4	26.7	15.8	15.1	27.2	12.0	12.6	5.6
Fished in past month (0/1)	0.84	0.67 ***	0.85	0.67 ***	0.75	0.60 +	0.97	0.74	0.86	0.72 +	0.85	0.74	0.61	0.51
Fished in past year (0/1)	0.95	0.84 ***	0.94	0.84 ***	0.96	0.77 **	1.00	0.91	0.95	0.91 *	1.00	0.92	0.83	0.68
Fish caught on the most recent trip (kg)	5.81	5.52	5.59	4.59 +	3.27	2.55	9.17	8.22	8.87	12.44	4.81	6.75	2.79	5.28
Assets and health														
Asset index (0-10)	2.92	4.81 ***	2.74	4.62 ***	2.50	4.52 ***	3.14	4.70 **	3.44	5.53 *	3.85	5.40 *	3.37	5.76 ***
Illness reported in past three months (0/1)	0.78	0.60 ***	0.76	0.64	0.89	0.67 **	0.73	0.49	0.79	0.43 *	0.66	0.58	0.83	0.56 +
Illness disrupted activities (0/1)	0.93	0.85 *	0.95	0.87 +	0.89	0.72	0.96	0.73 *	0.88	0.90	0.90	1.00	0.93	0.91
Perceptions of environmental contamination[1]														
Reports river contamination (0/1)	0.47	0.51	0.44	0.42	0.56	0.77 *	0.48	0.47	0.42	0.58	0.53	0.71 *	0.44	0.55 *
Reports air contamination (0/1)	0.22	0.25	0.22	0.21	0.36	0.39	0.13	0.18	0.13	0.34	0.13	0.34	0.31	0.30 *
Reports soil contamination (0/1)	0.20	0.23	0.21	0.22	0.23	0.36 *	0.14	0.21	0.19	0.28	0.12	0.14	0.25	0.17 +
Reports any contamination from oil co. (0/1)	0.41	0.46	0.36	0.34	0.57	0.81 *	0.49	0.51	0.38	0.47	0.31	0.66 +	0.36	0.44
Sample households	484	601	235	336	89	86	64	54	44	46	34	38	18	41
Sample communities	32	32	14	14	8	8	5	5	3	3	2	2	0	0

Italics indicate outcome variables for the multivariate analysis.

[1] These questions were asked of both male and female household heads. Results are mean values across all responding individuals.

+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Table 3. Predictors of livelihood outcomes (mean values by year).

Predictor	2001	2012
Household-level predictors		
Household size (#)	6.3	6.2
Age of head (years)	38.9	41.0
Head is female (0/1)	0.05	0.05
Head was born in the community (0/1)	0.27	0.38
Head does not speak Spanish (0/1)	0.09	0.04
Head completed primary education (0/1)	0.58	0.75
Head is Kichwa[1] (0/1)	0.48	0.56
Head is Shuar (0/1)	0.19	0.14
Head is Waorani (0/1)	0.13	0.09
Head is Cofán (0/1)	0.10	0.08
Head is Secoya (0/1)	0.08	0.06
Head is Mestizo (0/1)	0.04	0.07
Sample size (households)	476	599
Community-level predictors		
Community population (#)	178	279
Travel time to nearest city (hours)	3.40	2.46
Oil company employees (#)	7.04	8.75
Oil company assistance programs (#)	0.83	0.75
Sample size (communities)	32	32

[1] Reference category

Table 4. Two-step models of censored livelihood outcomes (odds ratios, coefficients and significance tests).

	Logit models (odds ratios)								Linear models (coefficients)							
Predictor	**OFE (participation)**				**Hunting (participation)**				**OFE (income)**				**Hunting (harvest)**			
	Model 1		Model 2		Model 3		Model 4		Model 5		Model 6		Model 7		Model 8	
Random effects model																
Oil company employees	1.02	*	-		0.99		-		0.00		-		0.01	**	-	
Oil company assistance programs	-		1.14	+	-		1.02		-		0.10	**	-		0.02	
Household size	1.07	*	1.07	*	1.07	*	1.07	*	0.01		0.01		0.00		0.00	
Age of head	0.97	***	0.97	***	0.99		0.99		0.01	+	0.01	+	0.01		0.01	+
Head is female	0.44	*	0.43	*	0.27	**	0.27	**	-0.16		-0.19		-0.19		-0.17	
Head was born in the community	0.82		0.80		1.24		1.24		-0.03		-0.06		0.05		0.06	
Head does not speak Spanish	1.81		1.76		0.38	*	0.38	*	-0.50	*	-0.52	*	0.01		0.00	
Head completed primary education	1.38		1.31		0.74		0.74		0.36	**	0.32	*	0.07		0.06	
Head is Shuar	2.02		2.13	+	0.88		0.89		0.02		0.07		-0.29	+	-0.29	+
Head is Waorani	6.04	**	6.58	**	4.54	**	4.41	**	0.61	+	0.56	+	0.36	*	0.41	*
Head is Cofán	2.23		2.09		3.26	*	3.57	*	0.02		0.00		0.24		0.17	
Head is Secoya	1.17		1.11		2.51		2.79	+	0.44		0.46		0.36	+	0.30	
Head is Mestizo	1.67		1.71		0.77		0.77		0.00		0.02		-0.06		-0.06	
Community population	1.02		1.03	*	1.00		1.00		0.02	**	0.02	**	-0.01		0.00	
Travel time to nearest city	1.08		1.08		1.09	+	1.09	+	-0.02		-0.02		0.01		0.01	
Year is 2012	0.77		0.72	+	0.38	***	0.38	***	0.40	***	0.42	***	-0.17	*	-0.20	**
Constant	0.90		0.78		2.67	*	2.62	*	5.70	***	5.60	***	2.15	***	2.10	***
Fixed effects model[1]																
Oil company employees	1.01	+	-		0.99	+	-		0.00		-		0.01	*	-	
Oil company assistance programs	-		1.07		-		0.98		-		0.10	*	-		0.00	
Sample size (households)	1075		1075		1075		1075		575		575		664		664	

[1] Models include controls and community-level fixed effects, not shown.
+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Table 5. Single-step models of continuous livelihood outcomes (coefficients and significance tests).

Predictor	Assets (index)				Agriculture (area)				Fishing (harvest)			
	Model 9		Model 10		Model 11		Model 12		Model 13		Model 14	
Random effects model												
Oil company employees	0.00		-		0.00		-		-0.01	+	-	
Oil company assistance programs	-		0.09	*	-		0.02		-		0.01	
Household size	0.05	**	0.06	**	0.02	**	0.02	**	0.03	**	0.03	**
Age of head	0.02	***	0.02	***	0.00	*	0.00	*	0.00		0.00	
Head is female	-0.64	**	-0.66	**	-0.06		-0.07		-0.30	*	-0.30	*
Head was born in the community	-0.09		-0.10		0.03		0.03		0.21	**	0.21	**
Head does not speak Spanish	-0.49	*	-0.51	*	-0.18	*	-0.18	*	-0.09		-0.09	
Head completed primary education	0.46	***	0.44	***	-0.01		-0.02		0.02		0.02	
Head is Shuar	0.03		0.04		-0.13		-0.13		-0.14		-0.15	
Head is Waorani	0.36		0.30		-0.04		-0.05		0.12		0.11	
Head is Cofán	0.78	*	0.77	*	-0.15		-0.15		0.13		0.15	
Head is Secoya	1.20	*	1.20	*	0.02		0.03		0.34		0.36	
Head is Mestizo	0.52	*	0.52	*	-0.15	+	-0.15	+	-0.17		-0.18	
Community population	0.00		0.00		-0.01	*	-0.01	*	-0.01	+	-0.01	*
Travel time to nearest city	-0.02		-0.02		-0.02		-0.02		-0.01		-0.01	
Year is 2012	1.71	***	1.71	***	-0.10	*	-0.10	*	-0.01		0.00	
Constant	1.29	***	1.22	***	0.82	***	0.80	***	1.20	***	1.18	***
Fixed effects model[1]												
Oil company employees	0.00		-		0.00		-		-0.01	*	-	
Oil company assistance programs	-		0.08	+	-		0.02		-		0.01	
Sample size (households)	1053		1053		1075		1075		1075		1075	

[1] Models include controls and community-level fixed effects, not shown.
+ p<0.10, * p<0.05, ** p<0.01, *** p<0.001

Figure 1. Map of the study communities.