Department of Economics
ISSN number 1441-5429

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Discussion Paper no. 2023-01

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Keywords: Fisheries decentralization , height-for-age z-score , propensity score, placebo

JEL Classification: Q22, Q28

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We would like to thank Moe Sin and Wisdom Akpalu for their invaluable discussant comments.

1. Introduction

Natural resources provide a wide range of services to people through the provision of food and materials, reduced damages from extreme weather events, the regulation of water, soil and climate, and non-material recreational, aesthetic, cultural and spiritual benefits (Food and Agriculture Organization, 2021). These ecosystem services may be particularly important in developing countries, given the greater dependency of local livelihoods on natural resources in those countries (Barbier, 2006). Recent estimates suggest that freshwater fisheries play a critical role in the provision of low-cost protein and employment in rural communities, where alternative sources are rare. McIntyre, Liermann and Revenga (2016) estimate that such fisheries globally provide the dietary animal protein necessary to sustain 158 million people, while Fluet-Chouinard, Funge-Smith and McIntyre (2018) argue that this figure may be as high as 200 million people, once household consumption is properly accounted for. Despite their importance, freshwater fisheries are typically neglected by governments (Fluet-Chouinard et al., 2018), with important consequences for their sustainability and subsequently the nutrient supplies they provide to people (Heilpern et al., 2021). Between 1970 and 2016, global migratory freshwater fish stocks declined on average by 76%, with unmanaged fisheries decreasing at the fastest rate (Deinet et al., 2020).

Although there are few certainties regarding how to end this decline, there has been a growing interest in co-management approaches, where different levels of government support the role of communities in actively managing the resource (Cohen et al., 2021). Underlying the promotion of co-management and more broadly, community-based natural resource management (CBNRM), is the assumption that users of the natural resource have extensive experience and knowledge regarding the resource's characteristics, and an interest in its sustainable management, leading to the development of better-informed regulations which may achieve sustainable high extraction levels. In addition, given local proximity and the web of social connections that keep communities together, those objectives would be achieved with lower enforcement and administrative costs (Ostrom, 1990).

Despite the long history of CBNRM (Brosius, Lowenhaupt, & Zerner, 1998) and its appeal in policy circles, the lack of empirical evidence about its impact, either on the environment or the households that rely on environmental services, raised the alarm that it was being approached as a panacea (Ostrom, Janssen, & Anderies, 2007; Young et al., 2018). This is illustrated by Evans et al. (2011), a meta-analysis of the impact of fisheries decentralization on human wellbeing in developing countries, who note two major limitations of the studies they reviewed: (1) none of the studies conducted a rigorous impact assessment which aimed to establish a causal impact of decentralization on any outcome, and (2) they all focused on local case studies, ignoring the potential impact of policies implemented at a national scale. In this paper we reduce these two gaps in knowledge through an analysis of the impact of decentralized fisheries management on child malnutrition, as implemented through Lao PDR's 2009 Fisheries Law.

Lao PDR freshwater fisheries contribute heavily to the local diet, with fish providing approximately 50% of the total protein as well as essential micronutrients including vitamins A and B12, iron, and zinc (Allison & Mills, 2018; Baran, Jantunen, & Chong, 2007). This importance is not equal across the country: fresh fish constitutes 25% of total food consumption in rural areas without roads compared with rural areas with roads and urban areas (20% and 16% respectively), measured as a proportion of total expenditure on food, estimated using data from the 2012/2013 Laos Expenditure and Consumption Survey in villages that had not benefited from this policy.

The Lao 2009 Fisheries Law included the decentralization of fisheries management at the village level as a central component of its fisheries policy. Local communities, through dedicated Fisheries Management Committees (FMCs), would be responsible for the definition of a range of possible management strategies, including the identification and management of conservation zones (i.e., no-take areas) as well as the regulation of fishing gear and methods, complementing a minimum standard of regulation at higher administrative levels (national, provincial or district). In its functioning, the FMC should be able to rely on the support of government officials, under the Ministry of Agriculture and Forestry, who were also involved in the formal recognition and, in many cases, promotion of this policy, formalising a co-management approach (Jentoft, McCay, & Wilson, 1998). The establishment of these committees was fast: in 2011, the Agricultural Census identified FMCs in approximately 24% of all villages in the country.

Although there were no national guidelines defining implementation priorities for the creation of FMCs, the formation of these local committees was likely not random. Anecdotal evidence suggests that distance from a river (as it influences both the costs and the benefits of any fisheries regulation), together with implementation costs (namely distance from administrative headquarters), played an important role in the decision of where to establish FMCs. Health outcomes likely played no role in the decision of where to establish FMCs given both the lack of information and the lack of focus by the Ministry of Agriculture and Forestry (MAF) officials in charge of this policy on those outcomes. However, areas with FMCs may be fundamentally different from those without, in ways that indirectly effect child nutrition. For example, villages closer to administrative headquarters may have greater access to public services such as electricity and piped water, both of which may lead to better nutrition outcomes. Given the potential bias introduced by program placement, a simple with-without comparison would be unlikely to provide a causal estimate of the impact of this policy. As in other studies (see Ferraro and Hanauer (2014) for a review), we address the potential confounding effect of these pre-program differences by estimating the propensity score as an approximation of the experimental ideal.

To measure the impact of establishing FMCs on human outcomes, we rely on data collected two years after the approval of the 2009 Fisheries Law, as part of the 2011 Lao Social Indicators Survey (LSIS). Similar to other Demographic and Health Surveys (DHS), the LSIS collected data on anthropometric measurements of young children. We will rely on measurements of height, and the computation of height-for-age z-scores (HAZ) as a measure of long-term health status. Given the timing of the survey, we focus on the effect of this policy change on children younger than 2 years old, as they are more likely to have experienced the impacts of FMCs for most of their life, while older children may have only experienced them after important growth milestones had already occurred (Victoria, 2009). Given differences in fish importance in the local diet, we are also particularly interested in the moderating effect of ex-ante economic conditions at the village level, and consider differences between three strata: urban villages, and rural villages with and without roads. We would expect isolated rural communities that rely more heavily on local food production, including local fisheries (Allison & Mills, 2018; Fluet-Chouinard et al., 2018), would also disproportionately be impacted by this change in policy.

Our results allow for two conclusions: decentralized management of natural resources mattered most where the resources are most important for local livelihoods (rural villages without roads) and benefited younger children (less than two years old) the most. These effects are large and precisely estimated: depending on the model specification, establishing an FMC leads to an increase in the HAZ of young children living in rural areas without road access by 1.23-0.97 standard deviations (SD).

These results have a causal interpretation if, controlling for observed characteristics that may have impacted on potential health outcomes, the formation of FMCs was ‘as if’ random. This is a strong but we believe defensible assumption in our case, even in the absence of data on pre-treatment outcomes which, following Dehejia & Wahba (1999), became the standard argument in favour of causal identification in this approach. The first reason why this assumption may hold is precisely the lack of data: even if MAF officials wanted to support this policy as a way to promote better nutrition outcomes (an argument that relies on their ability to both anticipate its effects and overcome a silo mentality that frequently settles between different line ministries), they would not have the data to directly target malnutrition, as the 2011 LSIS was the first of its kind in the country. Selection was then likely done on the basis of geographic and economic criteria, which we measure.

The second argument in favour of interpreting these results as causal is more statistical in nature. If important pre-treatment differences between villages with and without FMCs are driving our results, we would expect these to be persistent through time. As a result, we would expect to find similar differences in nutritional status between older children (i.e., those older than 2 years old) living in villages where FMCs were formed when compared with those same cohorts in villages without FMCs. However, we find no statistically significant effect of this policy on this subsample, suggesting that such pre-treatment differences did not exist in the first place and that our estimates among younger children reflect the policy change introduced by the 2009 Fisheries Law.

An alternative explanation is that the implementation of FMCs was accompanied by other changes that disproportionately improve young children's health. Ruling out this explanation requires the analysis of changes in health outcomes unlikely to have been influenced by fisheries decentralization. One such outcomes is child vaccination: an increase in vaccination of young children would likely reflect increased knowledge about child health (which could have translated into improved nutrition) that is unlikely to be driven by fisheries decentralization. However, we find no evidence supporting differences in vaccination rates among young children, suggesting that our estimates do not reflect unobserved determinants of potential health outcomes.

An important question is how did FMCs improve children's outcomes. We find support for increased fisheries productivity as one mechanism underlying these impacts. Using data from the almost contemporaneous Laos Expenditure and Consumption Survey 2011/12, we show that households in rural villages without roads significantly increased fish consumption. However, we find no evidence that this change is accompanied by increased labour allocation to fishing or investments in fishing equipment. One implication of these results is that improvements in nutritional status, likely mediated by increased consumption, were not achieved at a cost of over-exploitation of the resource since its devolution to local management.

The remainder of this paper proceeds as follows: Section 2 discusses the identification strategy, Section 3 describes the data, Section 4 presents the empirical results and a discussion and Section 5 provides concluding remarks.

2. Methodology

Following the formulation of the Rubin Causal Model (Holland, 1986), we would like to estimate the impact of fisheries decentralization on nutrition as:

$$TE = H_{iv}(D = 1) - H_{iv}(D = 0) \qquad (1)$$

where $H_{iv}(D = 1)$ refers to the nutritional outcome of a child i in village v where an FMC was established ($D = 1$) and $H_{iv}(D = 0)$ refers to the nutrition outcome of the *same child* had an FMC not been established (i.e., the counterfactual). This equation formalises the fundamental problem of impact evaluation, as half of the potential nutrition outcomes are missing.

Given this missingness problem, we can only estimate average treatment effects, defined as:

$$ATT = E[H_{iv}|D = 1] - E[H_{iv}|D = 0] \qquad (2)$$

Although there is no formally defined selection criteria that establish priorities for the implementation of decentralized local fisheries management, it is unlikely that the formation of FMCs was random. As a result, villages with FMCs may be fundamentally different from those without, invalidating a causal interpretation of the simple comparison of outcomes between areas with and without FMCs suggested in equation (2).

To overcome this selection bias, we follow Rosenbaum and Rubin (1983) in estimating a propensity score:

$$e(X_v) = Pr(D_i = 1|\boldsymbol{X_v}) \qquad (3)$$

i.e., we estimate the probability of village v establishing an FMC conditional on covariates ($\boldsymbol{X}_v$) that plausibly drive FMC establishment and childhood health outcomes but are not influenced by the establishment of the FMC itself.

The literature that uses estimates of the propensity scores to evaluate the impact of programs using observational data is diverse, covering a variety of policies that range from earlier applications in the evaluation of labour market training programs (Dehejia & Wahba, 2002; Heckman, Ichimura, & Todd, 1997) to antipoverty programs (Jalan & Ravallion, 2003), and access to microfinance (Diaz & Handa, 2006; Imai & Azam, 2010). In the context of the evaluation of environmental programs, this approach has been used to quantify the impact of air quality regulation (Greenstone, 2004; List, Millimet, Fredriksson, & McHone, 2003), payments for ecosystem services programs (Alix-Garcia, Shapiro, & Sims, 2012; Arriagada, Ferraro, Sills, Pattanayak, & Cordero-Sancho, 2012), farmland and ecosystem conservation (Ferraro et al., 2013; Joppa & Pfaff, 2010; Mezzatesta, Newburn, & Woodward, 2013), decentralized forest management (Oldekop et al., 2019) and, closer to the topic of this paper, the effect of decentralized fisheries management (Haque & Dey, 2016; Khan et al., 2012).

Because FMCs were formed at village level, we estimate the propensity score using confounders also measured at that level. As a result, the average treatment effect is estimated as:

$$ATT = E[H_{iv}|D = 1, e(\boldsymbol{X_v})] - E[H_{iv}|D = 0, e(\boldsymbol{X_v})] \qquad (4)$$

where H_{iv} is the nutritional outcome of a child i in village v only ensures that we account for the confounding effect of village characteristics. In other words, equation (4) would not account for the confounding effect driven by differences in child characteristics and their household environment, which were not included in equation (3). If, contrary to our assumption, villages with different potential health outcomes had a different probability of benefiting from fisheries decentralization, the difference estimated in equation (4) could not have a causal interpretation.

To address this potential problem, we use a double robust estimator, and estimate the effect of this policy using the following weighted OLS regression:

$$H_{iv} = \alpha + \beta_1 D_v + \boldsymbol{\theta}\, \boldsymbol{Z}_{iv} + \varepsilon_{iv} \qquad (5)$$

with weights defined as (Nichols, 2008):

$$Weight_v = \begin{cases} 1 & if\ D_v = 1 \\ \frac{e(\boldsymbol{X_v})}{(1-e(\boldsymbol{X_v}))} & if\ D_v = 0 \end{cases} \qquad (6)$$

While inverse probability weights make treatment and control groups similar with respect to village observable characteristics (allowing us to eliminate the selection bias that arises from non-random placement of FMC at the village level), the inclusion of $\boldsymbol{Z}_{iv}$, a vector of time invariant correlates of child nutrition status unaccounted when estimating $e(\boldsymbol{X_v})$ allows us to reduce remaining bias at the child, household and village level. The estimate of β_1 captures the effect of fisheries decentralization on nutritional status. Other uses of this double robust approach include the analysis of the impact of right heart catheterisation (Hirano & Imbens, 2001), in-hospital smoking cessation counselling (Austin, 2011) and post-AMI statin use (Austin & Mamdani, 2006), the effects of cellphone distraction on crash risk (Lu, Guo, & Li, 2020), the effects of full turnout in American presidential elections given non-voter political preferences (Brunell & DiNardo, 2017), and the effect of changes in worker characteristics on the distribution of wages (Altonji, Bharadwaj, & Lange, 2008; DiNardo, 2002). Estimating the effect of fisheries decentralization in both uncontrolled and controlled regressions (equations 4 and 5, respectively), also provides an indirect test of the our identification assumption: if MAF had taken into account differences in health status in their decision of where to facilitate local management of fisheries, accounting for such variables (as in equation (5)) should lead to estimates of the effect of the program that are distinct from those obtained when we do not account for such differences (as in equation (4)).

Given the timing of the outcome measurement, we focus our analysis on children younger than 2 years old at the time of the LSIS data collection. These children were more likely to have been exposed to the program during crucial stages of development (Victoria, 2009) compared with older children, who only experienced its impacts when their health status was likely already largely determined, and were less likely to catch-up from any previous health injuries. Among these children, we are particularly interested in the effect of this policy in communities that have the highest dependency on fisheries as alternate sources of nutrition and employment are rare (Allison & Mills, 2018; Fluet-Chouinard et al., 2018). Children living in these rural villages, particularly those without access to roads, are more likely to experience the impact from changes in fisheries management, if any.

2.1 Strengthening the causal interpretation of our estimates

As discussed in Imbens (2004) the plausibility of interpreting estimates based on the propensity score 'as if' experimental relies on whether one can meet two central assumptions: overlap (or probabilistic assignment) and unconfoundedness (or the conditional independence assumption). The first assumption requires that each unit (summarised by its propensity score, a function of its observable characteristics) can be in either the treatment or control group. Given this, the causal interpretation of analyses that rely on a specification of the propensity score that satisfies the common support restriction (Caliendo & Kopeinig, 2008), strengthened post-estimation by trimming the values of the propensity score (Imbens, 2015), are seen as more plausible. In the empirical analysis presented in the next section, we impose both restrictions.

The assumption of unconfoundedness (i.e., that there are no unobservable variables which both influence the probability of receiving treatment and the outcome variable), is both stronger and untestable. Previous work that evaluates the performance of propensity score estimators against experimental benchmarks (Dehejia & Wahba, 2002; Smith & Todd, 2001) concludes that the credibility of any causal claim relies on the quality of the data used to estimate the propensity score. Estimates of treatment effects are particularly convincing if based on a rich set of variables from high-quality datasets, which plausibly explain the decision of the program implementer. Caliendo & Kopeinig (2008) reviews this literature and provides a guide to the estimation of the propensity score, which we followed.

3. Data

We use three datasets, collected almost simultaneously in the period 2011-2013 to quantify the impact of decentralizing the management of local fisheries on child nutrition. Because all three datasets were collected after the implementation of the Laos Fisheries Law in 2009, we use a fourth dataset, the 2005 Population Census, as the source of pre-treatment variables used to estimate the probability of establishing local fisheries management committees. The 2011 Agricultural Census, fielded only two years after the approval of the Fisheries Law, is the source of information on whether an FMC had been formed in a village or not. Out of the 8643 villages in the census, 2089 (24%) reported having established an FMC, suggesting that the adoption of this policy was quite rapid.

The analysis of the placement of these committees, and in particular their distance to the closest river, confirms the not-random nature of this decision. Figure 1 presents the probability of FMC establishment as a function of distance to the nearest river (estimated using local polynomial regression) after merging the 2005 Population Census and 2011 Agricultural Census (N = 8215). This figure confirms anecdotal evidence that FMCs are more likely to be established in villages that are relatively close to rivers: in practice, the likelihood of an FMC being formed drops significantly for distances greater than 2km. Spatial data on the location of main rivers and tributaries in Laos is provided by the Greater Mekong Subregion Environment Operations Center (2021). Distance between each village and the nearest river was calculated using the dist2Line function from the geosphere package in R (Hijams, 2019). As a first step in making villages with and without FMCs comparable, we excluded 5130 villages with a distance to the nearest river greater than 2km, leaving 3085 remaining for the analysis.

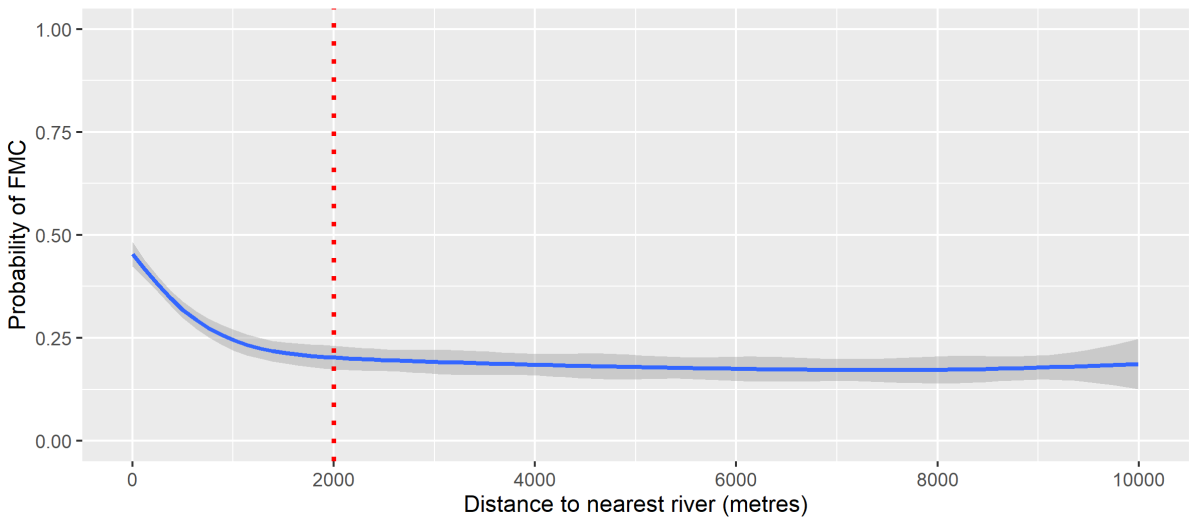

Fig. 1: Probability of FMC conditional on village distance to nearest river

Notes: Data on village distance calculated using village coordinates from the 2005 Laos Population Census and spatial data on the location of main rivers and tributaries in Laos from the Greater Mekong Subregion Environment Operations Center (2021). Data on village treatment status from 2011 Laos Agricultural Census. Probability of Fisheries Management Committee (FMC) calculated using local polynomial regression. Shaded area represents the 95% confidence interval.

We link the information of FMC existence from the Agricultural Census with two household surveys, the 2011/2012 Laos Social Indicator Survey (LSIS) and the 2012/2013 Lao Expenditure and Consumption Survey (LECS). Both surveys are nationally representative and collected by the Lao Bureau of Statistics using similar sampling strategies. We use these surveys as the source of data on nutritional status (LSIS) and on fish consumption and fishing activities (LECS). Unfortunately, no nationally representative survey collects both types of data.

The LSIS includes information regarding the health and wellbeing of individuals from 994 villages, including anthropometric indicators such as height-for-age z-score (HAZ), which we select as our main variable of interest as it reflects the nutritional and long-term health status of the individual rather than brief episodes of stress or illness (Sahn & Stifel, 2002). This survey also includes information on a large number of child and household level correlates of child nutrition status (for example sex and age of the child, mother's education, and household access to electricity and water), which we will use to strengthen the causal interpretation of our estimates of the nutritional impacts of this policy.

Figure 2 presents the distribution of HAZ for villages with and without an FMC, when we restrict the analysis to villages close to rivers and children less than 24 months old, and exclude observations with biologically infeasible values of HAZ.[3] Children in villages without FMCs appear to be slightly more malnourished (mean of -1.162) than those without FMCs (mean of -1.231), but this difference is not significant (p-value = 0.433).

[3] Here, and in the remainder of the analysis, we drop 109 observations with absolute value of HAZ greater than 6, as they are considered biologically infeasible (Nichols, Allender, Swinburn, & Orellana, 2021).

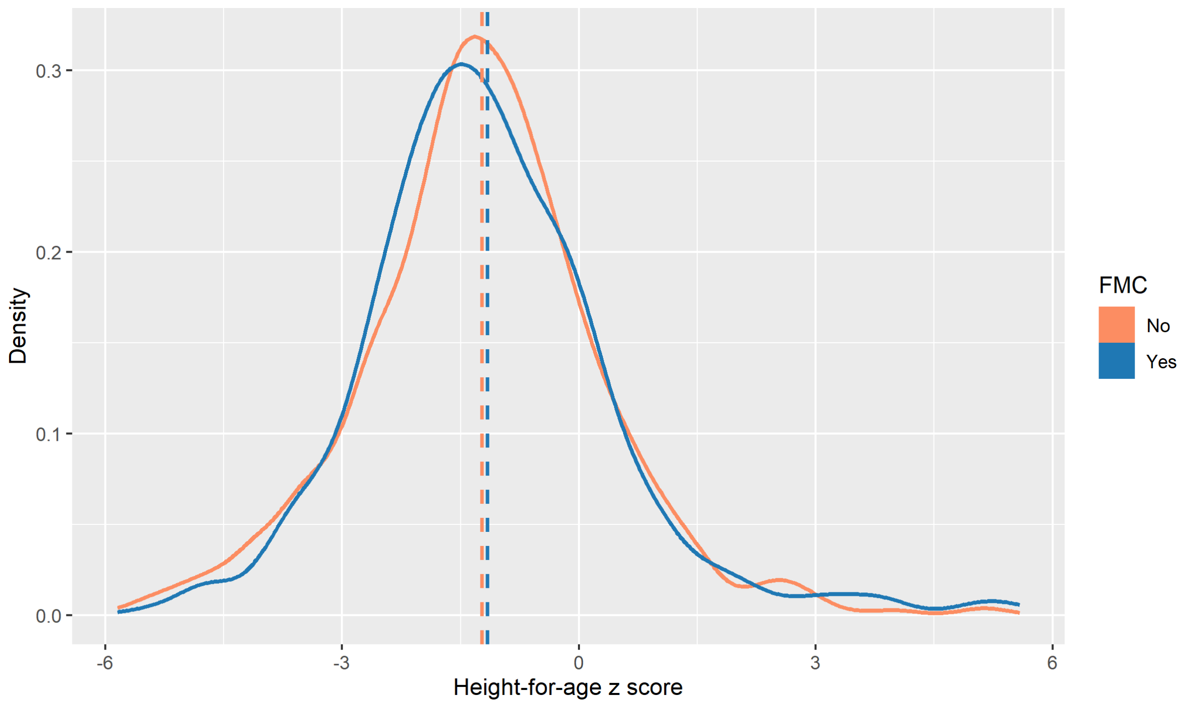

Fig. 2: Density plot of height-for-age z score by treatment group

Notes: Kernel density estimates of height-for-age z score (HAZ) for children with and without Fisheries Management Committees (FMCs). Data on child nutritional status from the Laos Social Indicator Survey 2011/2012. Data on village treatment status from 2011 Laos Agricultural Census. Dotted lines represent the mean HAZ for each group. Sample truncated to villages with distance to river less than 2km, and children less than 24 months old and with absolute value of HAZ less than 6.

This difference could be interpreted as the causal impact of fisheries decentralization on child nutrition only if there were no other pre-treatment differences between villages. To test this assumption, we turn to the 2005 Laos Population Census as the source of data on pre-treatment village level characteristics which plausibly influence both the decision to decentralize fisheries management and children's nutritional outcomes.

Although there are no national guidelines defining implementation priorities, anecdotal evidence suggests that, in addition to distance from a river, distance from administrative centres (that may influence both the costs and benefits of any regulation at the local level), as well as implementation costs played an important role in the decision of where to first establish FMCs. This intuition is shared by other studies that use distance to roads or administrative centres, or other geographic location information to estimate the probability of implementing different

CBNRM programs (Khan et al., 2012; Oldekop et al., 2019; Riehl et al., 2015). In addition, the explanation that fisheries decentralization was seen as a poverty alleviation program by local authorities cannot be easily dismissed.

In Table 1, we compare villages with and without FMCs in terms of characteristics that are plausibly related with the probability of establishing an FMC, measured in 2005 (ie, before fisheries decentralization was in place). The analysis of this table confirms that there were numerous differences between the two types of villages pre-implementation of this policy. For example, villages with FMCs are significantly smaller in population size and closer to rivers or tributaries (even after truncating the sample), are less likely to have access to electricity and water utilities although they are more likely to have access to healthcare, and are slightly more diverse in terms of the ethnic composition of their population, a potentially important determinant of the effectiveness of local cooperation (Cox, Lobel, & Mcleod, 1991; Hamer et al., 2018).[4] Households in those villages are also less likely to be ethnically Lao and are more likely to own farmland and participate in agricultural production. Contrary to what is conventionally suggested, they are also more remote (as measured by distance to administrative centres). Consistent with these differences, households in villages with an FMC are more likely to be poor.

[4] Ethnic heterogeneity is measured as a Herfindahl–Hirschman Index (HHI), using the percentage of each ethnic group from the 2005 Population Census.

Table 1: Comparing villages with and without FMC as at 2005

Variable	Village without FMC	Village with FMC	T-test difference
Distance (meters) from nearest river or tributary	679.423	480.697	198.726***
	(12.184)	(15.128)	
Mean travel time (min) to province capital	121.771	168.881	-47.110***
	(3.414)	(5.556)	
Mean travel time (min) to district capital	63.341	89.750	-26.410***
	(2.776)	(4.578)	
% of population living below the poverty line	34.563	40.097	-5.535***
	(0.423)	(0.598)	
Village population	658.081	530.549	127.533***
	(11.006)	(12.338)	
Dependency ratio	78.703	84.317	-5.615***
	(0.507)	(0.637)	
% of literate population	71.276	67.679	3.597***
	(0.518)	(0.706)	
Village with hospital (0 no; 1 yes)	0.086	0.109	-0.023**
	(0.006)	(0.010)	
Average age of women at first delivery	20.878	20.527	0.351***
	(0.029)	(0.039)	
% of population of ethno-linguistic category Lao	43.263	31.532	11.731***
	(1.006)	(1.349)	
Ethnicity concentration index	0.875	0.859	0.016**
	(0.004)	(0.006)	
% of households with farmland	71.796	80.176	-8.380***
	(0.628)	(1.520)	
% population unemployed	6.225	2.321	3.904***
	(0.389)	(0.230)	
% of population with main activity non-farm sector	20.541	11.165	9.376***
	(0.664)	(0.554)	
Village with electricity (0 no; 1 yes)	0.518	0.339	0.179***
	(0.011)	(0.015)	
Village with water supply (0 no; 1 yes)	0.150	0.045	0.105***
	(0.008)	(0.007)	
N:	2079	1006	

Notes: The value displayed for t-tests are the differences in the means across the groups. Data on village characteristics from 2005 Laos Population Census. Data on village treatment status from 2011 Laos Agricultural Census. Standard errors shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level respectively. Sample truncated to villages with distance to river less than 2km.

Despite its quality and the variety of information available, the LSIS does not include information on potential explanations for how fisheries decentralization may have impacted on health status, such as fish consumption, time spent fishing and investments in fishing equipment. This information is however available in LECS. The data suggests that households in villages where FMCs were created consumed more fish than those in villages without them:

on average, household fish consumption was valued at 287,683 Lao Kip (LAK) and 236,533 LAK, for households in villages with and without FMCs respectively, a difference that is statistically significant (p-value=0.0015). As with differences in nutritional outcomes, differences in fish consumption between these two types of villages cannot be interpreted as a causal effect of fisheries decentralization, given that pre-treatment differences may be driving this discrepancy.

4. Results

4.1. Estimating the average impact of fisheries decentralization

To account for differences in observable village level characteristics which contribute to FMC establishment and nutritional outcomes identified in Table 1, we estimate the probability of forming FMCs as a function of these variables (see Table A.1 for estimates of the propensity score). The balancing property is satisfied when imposing common support and using a specification that includes, in addition to the variables listed in Table 1, an interaction term of village distance from the nearest river with the percentage of Lao population and a squared term for the ethnicity concentration index. As discussed earlier, we find that distance to nearest river, province capital and district capital and the prevalence of poverty are all important predictors of the presence of an FMC.

Following Imbens (2015), we exclude the top and bottom 1% of the estimated propensity score distribution from the results that we discuss. Although the trimming of the propensity score is expected to improve the robustness of the analysis, as it excludes observations with very high/low probability of being included in the program (where the overlap assumption is likely to fail), it led to statistically significant differences between the two groups in four variables: percentage of households with farmland, percentage of unemployed population, percentage of population with main activity non-farm sector and access to water supply at village level (see Table A.2). In what follows, we present weighted OLS regressions with trimming but our conclusions are generally robust to these decisions (see Table A.6 for results in full sample).

The weighted OLS estimates of the average treatment effect of fisheries decentralization on the nutritional status of young children living in rural villages with and without roads are shown in Table 2. Model (1) is our base model and controls for treatment status (whether an FMC is established or not, defined at village level). Model (2) includes all of the variables in model (1) and children's characteristics (age and sex of the child, as well as whether the child was measured while standing). Finally, model (3) includes all variables in model (2) as well as demographic controls, including the sex and ethnicity of the household head, and the mother's education level, and household living conditions controls, such as access to electricity or piped water (see Table A.3 for full results).

The estimates of the impact of this policy on children under 2 years old in villages without access to roads are precisely estimated (all estimates significant at the 1% level) and economically important: fisheries decentralization led to average gains in HAZ between 1.234 (model 1, uncontrolled specification) and 0.970 (model 3, with the largest set of controls). As expected, and reflecting the fact that MAF was unlikely to have taken differences in such confounders when promoting this policy, these estimates are not statistically different from each other (Chi-square (1) = 2.10, p-value=0.148). However, children living in villages with access to markets (i.e., rural areas with road access) benefited much less, and the estimated effect of this policy becomes insignificant once we account for child demographic characteristics and living conditions.

Table 2: The impact of fisheries decentralization on the nutrition of young children

Dependent variable:	HAZ		
	(1)	(2)	(3)
FMC X Rural village with no road (0 no; 1 yes)	1.234***	1.115***	0.970***
	(0.352)	(0.347)	(0.326)
FMC X Rural village with road (0 no; 1 yes)	0.413*	0.287	0.238
	(0.241)	(0.237)	(0.216)
FMC (0 no; 1 yes)	-0.323	-0.239	-0.243
	(0.203)	(0.201)	(0.185)
Rural village with no road (0 no; 1 yes)	-0.587***	-0.618***	-0.183
	(0.217)	(0.216)	(0.230)
Rural village with road (0 no; 1 yes)	-0.246*	-0.291**	-0.0694
	(0.126)	(0.131)	(0.126)
Child controls	No	Yes	Yes
Demographic and living condition controls	No	No	Yes
N	1,413	1,413	1,350
R-squared	0.017	0.135	0.178

Notes: Weighted OLS estimates of the effect of establishing a Fisheries Management Committee (FMC) on young children's height-for-age z-score (HAZ). Robust standard errors clustered at the village level in parentheses. ***, **, * indicates statistical significance at the 1%, 5% and 10% level respectively. Sample truncated to villages with distance to river less than 2km, children less than 24 months old and with absolute value of HAZ less than 6, and propensity score within the 1-99 percentiles of its distribution. Data on HAZ and other child and household level controls from the Laos Social Indicator Survey 2011/2012. Data on village treatment status from 2011 Laos Agricultural Census. Sample size of young children living in urban, rural with road and rural without road villages in model (1) is 321, 887 and 205 respectively. See Table A.3 for full results.

4.2. Robustness checks

4.2.1 Effect of FMCs on older children

One possible alternative explanation for the results presented above is that villages where FMCs were established simply differed in other pre-treatment determinants of potential health outcomes. Because some of these determinants are likely unobserved, we cannot directly rule out this explanation. However, it seems plausible that both young and older children would benefit from such unobserved confounders, as these supposed differences were present before treatment. As a result, we would expect to observe a similar effect among older children. Table 3 presents the estimates for the effect of FMCs on the HAZ of older children, defined as being between 24 and 60 months old. As shown, we find no such effect (see Table A.4 for full results).

Table 3: The impact of fisheries decentralization on the nutrition of older children

Dependent variable:	HAZ		
	(1)	(2)	(3)
FMC X Rural village with no road (0 no; 1 yes)	-0.0372	-0.112	-0.142
	(0.350)	(0.342)	(0.298)
FMC X Rural village with road (0 no; 1 yes)	-0.119	-0.164	-0.0445
	(0.271)	(0.268)	(0.221)
FMC (0 no; 1 yes)	0.263	0.304	0.102
	(0.243)	(0.242)	(0.200)
Rural village with no road (0 no; 1 yes)	-0.527**	-0.506**	-0.0391
	(0.209)	(0.206)	(0.230)
Rural village with road (0 no; 1 yes)	-0.370***	-0.341***	-0.111
	(0.124)	(0.121)	(0.128)
Child controls	No	Yes	Yes
Demographic and living condition controls	No	No	Yes
N	1,851	1,851	1,678
R-squared	0.018	0.045	0.135

Notes: Weighted OLS estimates of the effect of establishing a Fisheries Management Committee (FMC) on older children's height-for-age z-score (HAZ). Robust standard errors clustered at the village level in parentheses. ***, **, * indicates statistical significance at the 1%, 5% and 10% level respectively. Sample truncated to villages with distance to river less than 2km, children between 24 and 60 months old and with absolute value of HAZ less than 6, and propensity score within the 1-99 percentiles of its distribution. Data on HAZ and other child and household level controls from the Laos Social Indicator Survey 2011/2012. Data on village treatment status from 2011 Laos Agricultural Census. Sample size of children living in urban, rural with road and rural without road villages in model (1) is 676, 2131 and 457 respectively. See Table A.4 for full results.

4.2.2 Placebo test

Another possible explanation for the results presented in Section 4.1 is that villages which established FMCs were simultaneously provided with other policies or government support which increased health outcomes and therefore HAZ. To test this hypothesis, we can estimate the effect of fisheries decentralization on a health outcome that plausibly reflects any contemporaneous unobserved health confounders, including policies or government support, but is implausibly linked with changes in fisheries management. One such outcome, for which we have data, is child vaccination. Rejecting the null hypothesis of no effect of fisheries decentralization on child vaccination would naturally question the causal nature of the impacts identified above, while failure to reject such an effect is suggestive that there are no meaningful unmeasured confounders of health outcomes that came simultaneously with the establishment of FMCs that could potentially explain our results.

Table 4 presents the weighted OLS estimates regression of the effect of FMCs on vaccination decisions for young children, a dummy variable that is equal to 1 if the child received any vaccine, using the same specification as equations (4)-(5) (see Table A.5 for full results). Regardless of the specification, FMCs have no significant impact on the rate of vaccination.

Table 4: Effect of fisheries decentralization on vaccination decisions for young children

Dependent variable:	Child received any vaccination (0 no; 1 yes)		
	(1)	(2)	(3)
FMC X Rural village with no road (0 no; 1 yes)	0.106	0.114	0.121
	(0.116)	(0.116)	(0.124)
FMC X Rural village with road (0 no; 1 yes)	-0.0745	-0.0633	-0.0276
	(0.0880)	(0.0860)	(0.0851)
FMC (0 no; 1 yes)	0.0994	0.0902	0.0760
	(0.0771)	(0.0755)	(0.0750)
Rural village with no road (0 no; 1 yes)	-0.0466	-0.0452	-0.134*
	(0.0614)	(0.0619)	(0.0697)
Rural village with road (0 no; 1 yes)	0.0112	0.0190	-0.0574
	(0.0427)	(0.0416)	(0.0439)
Child controls	No	Yes	Yes
Demographic and living condition controls	No	No	Yes
N	1,413	1,413	1,350
R-squared	0.011	0.054	0.079

Notes: Weighted OLS estimates of the effect of establishing a Fisheries Management Committee (FMC) on vaccination decisions for young children. Robust standard errors clustered at the village level in parentheses. ***, **, * indicates statistical significance at the 1%, 5% and 10% level respectively. Sample truncated to villages with distance to river less than 2km, children less than 24 months old and with absolute value of HAZ less than 6, and propensity score within the 1-99 percentiles of its distribution. Data on vaccination decisions and other child and household level controls from the Laos Social Indicator Survey 2011/2012. Data on village treatment status from 2011 Laos Agricultural Census. Sample size of children living in urban, rural with road and rural without road villages in model (1) is 321, 887 and 205 respectively. See Table A.5 for full results.

4.3. Mechanisms

We hypothesize that increases in fish consumption is one mechanism through which fisheries decentralization impacts on HAZ. Although we would like to examine the effect of establishing an FMC on fish consumption, and then the effects of changes in this variable on nutritional status following a traditional mediation analysis (MacKinnon, Fairchild, & Fritz, 2007), that is not possible given the limitations of our data: as mentioned above, there is no dataset that measures both economic activities and anthropometric indicators. Hence, we are limited to estimate the analogue of equation (5) where the dependent variable is fish consumption, measured as the value of fish consumed by the household during the survey period, expressed in the local currency (Lao Kip, LAK; in 2012, 1 US$~10,000 LAK). Table 5 presents these estimates.

Model (1), (2) and (3) find a positive effect of FMCs on the value of household fish consumption at 66,791, 69,643, 67,991 LAK respectively. These estimates are significant at the 10% level, increasing to 5% in model (3) after controlling for seasonality. For households residing in rural areas without a road, the effect size of FMCs on fish consumption is approximately doubled: 151,278, 153,451 and 155,235 LAK for models (1), (2) and (3) respectively. These estimates are all significant at the 5% level. This difference in magnitude between rural areas with and without a road reflects our findings in Table 2 and is consistent with the explanation that rural communities with no roads have the highest reliance on fisheries, and therefore would benefit the most given an improvement in the management of the resource.

Table 5: Effect of fisheries decentralization on fish consumption

Dependent variable:	Household fish consumption in past month		
	(1)	(2)	(3)
FMC X Rural village with no road (0 no; 1 yes)	151,278**	153,541**	155,235**
	(73,672)	(75,107)	(72,666)
FMC X Rural village with road (0 no; 1 yes)	66,791*	69,643**	67,991**
	(34,039)	(33,680)	(33,671)
FMC (0 no; 1 yes)	-26,569	-27,603	-26,151
	(28,455)	(27,974)	(27,624)
Rural village with no road (0 no; 1 yes)	-92,385**	-90,345**	-96,157**
	(35,629)	(37,746)	(38,477)
Rural village with road (0 no; 1 yes)	-26,124	-24,207	-26,880
	(17,491)	(17,870)	(18,141)
Household characteristics	No	Yes	Yes
Seasonality	No	No	Yes
Observations:	1,207	1,207	1,207
R-squared	0.031	0.049	0.050

Notes: Weighted OLS estimates of the effect of establishing a Fisheries Management Committee (FMC) on fish consumption. Robust standard errors clustered at the village level in parentheses. ***, **, * indicates statistical significance at the 1%, 5% and 10% level respectively. Sample truncated to villages with distance to river less than 2km, propensity score within the 1-99 percentiles. 47 outliers of fish consumption observations (identified using the hadimvo function in Stata) were excluded from the analysis. Fish consumption valued in LAK (9,583.36 LAK ≈ 1 USD). Productive assets index estimated as the first principal component of the value of productive assets owned by the household. Data on village treatment status from 2011 Laos Agricultural Census. Fish consumption data and household level controls from the 2012/2013 Lao Expenditure and Consumption Survey. See Table A.7 for full results.

One possible concern with this result is that it could indicate that after decentralization, households are simply exploring the resource in a much more intensive way, perhaps because other regulations established at a non-local level are no longer enforced. If this were the case, households would be trading-off natural capital (fish stocks) with human capital (health status of the next generation). Although we do not have measures of fish stocks in any large dataset, and as such are incapable of directly testing this hypothesis, we can estimate the effect of fisheries decentralization on two variables that we would expect to be associated with such over-exploitation of the resource: labour allocated to fishing and investment in fishing equipment.

Table 6 presents the effect of FMCs on three fishing inputs: labour allocated to fishing, ownership of a fishing boat, and ownership of fishing net. We find no significant impact of creating an FMC on any of these outcomes. Together with the results presented in Table 5, this suggests that fisheries decentralization increases fishery productivity, allowing for increased fish consumption without accompanying increases in labour allocated to fishing or investments in fishing equipment. This result is consistent with the previous findings of increased fisher income and household expenditure resulting from Bangladeshi fisheries decentralization policy (Haque & Dey, 2016; Khan et al., 2012).

Table 6: Effect of fisheries decentralization on fishing inputs

Dependent variable:	Time fishing by household in past 24 hours			Household owns fishing net (0 no; 1 yes)			Household owns boat (0 no; 1 yes)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
FMC X Rural village with road (0 no; 1 yes)	0.00719	-0.0189	-0.0106	0.0963	0.128	0.109	0.105	0.0981	0.0980
	(0.477)	(0.484)	(0.485)	(0.121)	(0.116)	(0.117)	(0.115)	(0.117)	(0.117)
FMC X Rural village with no road (0 no; 1 yes)	0.555	0.570	0.561	0.102	0.121	0.140	0.272	0.256	0.257
	(0.759)	(0.763)	(0.768)	(0.165)	(0.157)	(0.132)	(0.247)	(0.246)	(0.247)
FMC (0 no; 1 yes)	0.453	0.460	0.452	0.0131	-0.00299	0.0132	-0.0755	-0.0679	-0.0678
	(0.409)	(0.406)	(0.407)	(0.0989)	(0.0944)	(0.0954)	(0.0891)	(0.0912)	(0.0909)
Rural village with no road (0 no; 1 yes)	0.220	0.116	0.144	0.202*	0.230**	0.167**	0.0978	0.116	0.116
	(0.424)	(0.433)	(0.456)	(0.113)	(0.103)	(0.0834)	(0.182)	(0.181)	(0.183)
Rural village with road (0 no; 1 yes)	0.146	0.120	0.132	0.0680	0.0819	0.0542	0.0938	0.104	0.103
	(0.283)	(0.288)	(0.293)	(0.0737)	(0.0744)	(0.0683)	(0.0799)	(0.0803)	(0.0817)
Household characteristics	No	Yes	Yes	No	Yes	Yes	No	Yes	Yes
Seasonality	No	No	Yes	No	No	Yes	No	No	Yes
Observations	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254
R-squared	0.019	0.036	0.036	0.032	0.076	0.100	0.035	0.043	0.043

Notes: Weighted OLS estimates of the effect of establishing a Fisheries Management Committee (FMC) on fishing inputs. Robust standard errors clustered at the village level in parentheses. ***, **, * indicates statistical significance at the 1%, 5% and 10% level respectively. Sample truncated to villages with distance to river less than 2km and propensity score within the 1-99 percentiles. Productive assets index estimated as the first principal component of the value of productive assets owned by the household. Data on village treatment status from 2011 Laos Agricultural Census. Dependent variables and household level controls from the 2012/2013 Lao Expenditure and Consumption Survey. See Table A.8 for full results.

5. Conclusion

Freshwater fisheries provide people in developing countries with nutrition and employment, which are especially valuable in rural and isolated communities where alternate sources of both are rare. The health of freshwater ecosystems relies on effective ways to avoid 'open access', which would leave them susceptible to over-exploitation. Despite a paucity of causal evidence on its impact on either human or environmental outcomes, fisheries decentralization is used as one possible solution to the 'tragedy of the commons' (Hardin, 1968).

This study evaluates the impact of fisheries decentralization, promoted in Lao PDR after the approval of the 2009 Fisheries Law, on nutrition outcomes. We address two key gaps in knowledge about the impact of fisheries decentralization, as we estimate the causal impact of this approach to fisheries management in the context of a nationally implemented program. We use a double robust design, combining weights based on the propensity score (estimated using pre-treatment variables which plausibly explain the decision to decentralize the management of local fisheries through the creation of dedicated Fisheries Management Committees) with a regression approach that controls for other potential confounders, measured at the household and child level.

We find that fisheries decentralization decreases child malnutrition, driven by children who were exposed to the program for most (or all) of their life and who live in isolated communities which are heavily reliant on fisheries as a source of nutrition. We rule out the alternative explanations of these results, where nutritional gains are driven by unmeasured confounders of potential health outcomes or other changes implemented simultaneously with the FMCs, by estimating the effect of fisheries decentralization on older children and child vaccination decisions respectively. We find no support for these relations.

Using data from an almost contemporaneous nationally representative expenditure and consumption survey, we find that fisheries decentralization leads to greater fish consumption, supporting the hypothesis that this is one of the mechanisms underlying nutritional gains. Analysis of the same data confirms that fisheries decentralization had no significant impact on labour allocated to fishing or on investments in fishing equipment. Taken together, this suggests that improved fisheries productivity (rather than over-exploitation of the resource) drives nutritional gains.

These results have direct implications for the way that FMCs are created, as they suggest that priority should be given to rural communities with higher dependency on natural resources for local livelihoods in future expansion of this policy. Although we equated the dependency of livelihoods on natural resources with lack of access to roads, future work can potentially explore other, more direct, indicators of this relation.

Our results suggest further questions that can potentially be addressed in future research, such as those concerning the dynamic effects of decentralization. We evaluated the impact of this policy shortly after its implementation, and although this is positive in terms of the identification of its impacts, it is limited in what can be said about the policy's sustainability. It is, for example, possible that increased fish stocks attracted investment in the activity that leads to their over-exploitation.

Concerns about sustainable exploitation of this resource lead to two additional questions. The first is how to unpack the contents of fisheries decentralization. In this study, we equated it with the establishment of local FMCs, but as the 2009 Fisheries Law makes clear, these committees have a vast range of responsibilities, from the establishment of conservation zones to monitoring locally defined regulations. There is no universal blueprint, and different FMCs make different choices. Although we overlooked this complexity due to data limitations, future research could benefit from an analysis of which 'package' of rules seems most effective, even if the causal identification of the importance of each is complicated. Finally, given the lack of data, we are silent on any direct impact of fisheries decentralization on indicators of ecosystem health, such as fish stocks and biodiversity. As over-exploitation threatens the health of freshwater ecosystems in the Lower Mekong Basin, this should be an area of urgent concern and active research.

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Appendix

Table A.1: Propensity score estimation

Dependent variable:	Fisheries Management Committee (0 no; 1 yes)	
	Coefficient	Std Error
Distance (meters) from nearest river or tributary	-0.000460***	(6.19e-05)
Mean travel time (min) to province capital	0.00107***	(0.000334)
Mean travel time (min) to district capital	-0.000902**	(0.000389)
Village population	-3.54e-05	(7.43e-05)
Dependency ratio	-0.00143	(0.00160)
% of literate population	0.00879***	(0.00168)
Village with hospital (0 no; 1 yes)	0.191**	(0.0844)
Average age of women at first delivery	-0.0327	(0.0221)
% of population living below the poverty line	0.00741***	(0.00215)
% of population of ethno-linguistic category Lao	-0.00285***	(0.000901)
Ethnicity concentration index	0.596	(1.159)
% of households with farmland	0.00119	(0.000824)
% population unemployed	-0.00110	(0.00285)
% of population with main activity non-farm sector	-0.00455**	(0.00178)
Village with electricity (0 no; 1 yes)	-0.220***	(0.0656)
Village with water supply (0 no; 1 yes)	-0.209	(0.127)
Distance to river Lao ethnicity interaction	2.52e-06**	(1.05e-06)
Ethnicity concentration index squared	-1.434	(1.883)
Constant	0.593	(0.931)
N	3085	

Notes: Data on village treatment status from 2011 Laos Agricultural Census. Data on other village characteristics from 2005 Laos Population Census. ***, **, * indicates statistical significance at the 1%, 5% and 10% level respectively. Sample truncated to villages with distance to river less than 2km.

Table A.2: Balance on village characteristics across FMC groups with propensity score weight after trimming

	Village without FMC	Village with FMC	T-test difference
Distance (meters) from nearest river or tributary	487.512	486.483	1.029
	(10.518)	(15.464)	
Mean travel time (min) to province capital	161.149	158.687	2.461
	(5.172)	(5.279)	
Mean travel time (min) to district capital	89.023	86.579	2.444
	(4.520)	(4.572)	
Village population	522.491	524.253	-1.762
	(8.781)	(12.103)	
Dependency ratio	84.663	84.030	0.633
	(0.530)	(0.657)	
% of literate population	66.935	67.430	-0.495
	(0.570)	(0.736)	
Village with hospital (0 no; 1 yes)	0.107	0.098	0.009
	(0.009)	(0.010)	
Average age of women at first delivery	20.509	20.554	-0.045
	(0.031)	(0.040)	
% of population living below the poverty line	40.091	39.453	0.638
	(0.499)	(0.604)	
% of population of ethno-linguistic category Lao	31.217	32.644	-1.428
	(1.048)	(1.406)	
Ethnicity concentration index	0.867	0.868	-0.001
	(0.005)	(0.006)	
% of households with farmland	80.618	78.639	1.979*
	(0.639)	(0.816)	
% population unemployed	1.565	2.166	-0.601***
	(0.103)	(0.208)	
% of population with main activity non-farm sector	9.081	10.927	-1.846***
	(0.329)	(0.552)	
Village with electricity (0 no; 1 yes)	0.337	0.349	-0.012
	(0.011)	(0.016)	
Village with water supply (0 no; 1 yes)	0.024	0.039	-0.015**
	(0.003)	(0.006)	
Observations	1810	946	

Notes: The value displayed for t-tests are the propensity score weighted differences in the means across the groups. Data on village treatment status from 2011 Laos Agricultural Census. Data on other village characteristics from 2005 Laos Population Census. Standard errors shown in parentheses. ***, **, and * indicate significance at the 1%, 5%, and 10% level respectively. Sample truncated to villages with distance to river less than 2km and propensity score within the 1-99 percentiles of its distribution.

Table A.3: The impact of fisheries decentralization on the nutrition of young children

Dependent variable:	Height-for-age z-score (HAZ)		
	(1)	(2)	(3)
FMC X Rural village with no road (0 no; 1 yes)	1.234***	1.115***	0.970***
	(0.352)	(0.347)	(0.326)
FMC X Rural village with road (0 no; 1 yes)	0.413*	0.287	0.238
	(0.241)	(0.237)	(0.216)
FMC (0 no; 1 yes)	-0.323	-0.239	-0.243
	(0.203)	(0.201)	(0.185)
Rural village with no road (0 no; 1 yes)	-0.587***	-0.618***	-0.183
	(0.217)	(0.216)	(0.230)
Rural village with road (0 no; 1 yes)	-0.246*	-0.291**	-0.0694
	(0.126)	(0.131)	(0.126)
Sex (0 female; 1 male)		-0.251***	-0.292***
		(0.0833)	(0.0885)
Child measured standing (0 no; 1 yes)		0.648***	0.721***
		(0.212)	(0.218)
Age (months)		-0.0779***	-0.0804***
		(0.00761)	(0.00768)
Mother's education: primary (0 no; 1 yes)			0.204*
			(0.123)
Mother's education: secondary (0 no; 1 yes)			0.291*
			(0.150)
Mother's education: higher (0 no; 1 yes)			0.112
			(0.182)
Dependence ratio			0.181
			(0.408)
Mothers age <20 at birth (0 no; 1 yes)			-0.352*
			(0.195)
Mothers age 20-34 at birth (0 no; 1 yes)			-0.154
			(0.148)
Ethnicity of household head Lao (0 no; 1 yes)			0.171*
			(0.104)
Ethnicity of household head Khmu (0 no; 1 yes)			0.0373
			(0.171)
Ethnicity of household head Hmong (0 no; 1 yes)			-0.0169
			(0.193)
Birth order			-0.129*
			(0.0721)
Sex of household head (0 female; 1 male)			0.000396
			(0.162)
Household is owned by household member (0 no; 1 yes)			0.163
			(0.236)
Household has electricity (0 no; 1 yes)			0.228*
			(0.119)
Household with piped water source (0 no; 1 yes)			-0.0753
			(0.139)
Household with improved sanitation (0 no; 1 yes)			0.171
			(0.117)
Positive salt iodization test (0 no; 1 yes)			0.0574
			(0.110)
Constant	-1.060***	-0.00230	-0.505
	(0.0988)	(0.140)	(0.443)
N	1,413	1,413	1,350
R-squared	0.017	0.135	0.178

Notes: Weighted OLS estimates of the effect of establishing a Fisheries Management Committee (FMC) on young children's height-for-age z-score (HAZ). Robust standard errors clustered at the village level in parentheses. ***, **, * indicates statistical significance at the 1%, 5% and 10% level respectively. Sample truncated to villages with distance to river less than 2km, children aged less than 24 months old with absolute value of HAZ less than 6 and propensity score within the 1-99 percentiles of its distribution. Data on HAZ and other child and household level controls from the Laos Social Indicator Survey 2011/2012. Data on village treatment status from 2011 Laos Agricultural Census. Sample size of young children living in urban, rural with road and rural without road villages in model (1) is 321, 887 and 205 respectively.

Table A.4: The impact of fisheries decentralization on the nutrition of older children

Dependent variable:	Height-for-age z-score (HAZ)		
	(1)	(2)	(3)
FMC X Rural village with no road (0 no; 1 yes)	-0.0372	-0.112	-0.142
	(0.350)	(0.342)	(0.298)
FMC X Rural village with road (0 no; 1 yes)	-0.119	-0.164	-0.0445
	(0.271)	(0.268)	(0.221)
FMC (0 no; 1 yes)	0.263	0.304	0.102
	(0.243)	(0.242)	(0.200)
Rural village with no road (0 no; 1 yes)	-0.527**	-0.506**	-0.0391
	(0.209)	(0.206)	(0.230)
Rural village with road (0 no; 1 yes)	-0.370***	-0.341***	-0.111
	(0.124)	(0.121)	(0.128)
Sex (0 female; 1 male)		-0.0708	-0.0663
		(0.0699)	(0.0711)
Age (months)		-0.0225***	-0.0212***
		(0.00359)	(0.00363)
Mother's education: primary (0 no; 1 yes)			0.174
			(0.110)
Mother's education: secondary (0 no; 1 yes)			0.254**
			(0.119)
Mother's education: higher (0 no; 1 yes)			0.292
			(0.198)
Dependence ratio			0.177
			(0.304)
Mothers age <20 at birth (0 no; 1 yes)			-0.482**
			(0.188)
Mothers age 20-34 at birth (0 no; 1 yes)			-0.237
			(0.162)
Ethnicity of household head Lao (0 no; 1 yes)			0.542***
			(0.0902)
Ethnicity of household head Khmu (0 no; 1 yes)			0.00235
			(0.114)
Ethnicity of household head Hmong (0 no; 1 yes)			0.0633
			(0.144)
Birth order			-0.122**
			(0.0585)
Sex of household head (0 female; 1 male)			0.295***
			(0.111)
Household is owned by household member (0 no; 1 yes)			-0.600
			(0.446)
Household has electricity (0 no; 1 yes)			0.153
			(0.106)
Household with piped water source (0 no; 1 yes)			-0.0493
			(0.112)
Household with improved sanitation (0 no; 1 yes)			0.203***
			(0.0739)
Positive salt iodization test (0 no; 1 yes)			0.119
			(0.0999)
Constant	-1.581***	-0.619***	-0.767
	(0.0844)	(0.180)	(0.531)
N	1,851	1,851	1,678
R-squared	0.018	0.045	0.135

Notes: Weighted OLS estimates of the effect of establishing a Fisheries Management Committee (FMC) on older children's height-for-age z-score (HAZ). Robust standard errors clustered at the village level in parentheses. ***, **, * indicates statistical significance at the 1%, 5% and 10% level respectively. Sample truncated to villages with distance to river less than 2km, children aged between 24 and 60 months old with absolute value of HAZ less than 6 and propensity score within the 1-99 percentiles of its distribution. Data on HAZ and other child and household level controls from the Laos Social Indicator Survey 2011/2012. Data on village treatment status from 2011 Laos Agricultural Census. Sample size of older children living in urban, rural with road and rural without road villages in model (1) is 676, 2131 and 457 respectively.

Table A.5: Effect of fisheries decentralization on vaccination decisions for young children

Dependent variable:	Child received any vaccination (0 no; 1 yes)		
	(1)	(2)	(3)
FMC X Rural village with no road (0 no; 1 yes)	0.106	0.114	0.121
	(0.116)	(0.116)	(0.124)
FMC X Rural village with road (0 no; 1 yes)	-0.0745	-0.0633	-0.0276
	(0.0880)	(0.0860)	(0.0851)
FMC (0 no; 1 yes)	0.0994	0.0902	0.0760
	(0.0771)	(0.0755)	(0.0750)
Rural village with no road (0 no; 1 yes)	-0.0466	-0.0452	-0.134*
	(0.0614)	(0.0619)	(0.0697)
Rural village with road (0 no; 1 yes)	0.0112	0.0190	-0.0574
	(0.0427)	(0.0416)	(0.0439)
Sex (0 female; 1 male)		-0.0383	-0.0397
		(0.0281)	(0.0280)
Age (months)		0.0132***	0.0125***
		(0.00197)	(0.00189)
Mother's education: primary (0 no; 1 yes)			-0.00435
			(0.0411)
Mother's education: secondary (0 no; 1 yes)			-0.0671
			(0.0480)
Mother's education: higher (0 no; 1 yes)			-0.148**
			(0.0653)
Dependence ratio			-0.126
			(0.132)
Mothers age <20 at birth (0 no; 1 yes)			-0.0584
			(0.0738)
Mothers age 20-34 at birth (0 no; 1 yes)			-0.0335
			(0.0581)
Ethnicity of household head Lao (0 no; 1 yes)			-0.0179
			(0.0394)
Ethnicity of household head Khmu (0 no; 1 yes)			-0.0306
			(0.0566)
Ethnicity of household head Hmong (0 no; 1 yes)			-0.0229
			(0.0695)
Birth order			-0.0132
			(0.0253)
Sex of household head (0 female; 1 male)			-0.0738
			(0.0568)
Household is owned by household member (0 no; 1 yes)			0.0762
			(0.108)
Household has electricity (0 no; 1 yes)			-0.0428
			(0.0416)
Household with piped water source (0 no; 1 yes)			0.00214
			(0.0416)
Household with improved sanitation (0 no; 1 yes)			-0.105***
			(0.0335)
Positive salt iodization test (0 no; 1 yes)			0.0396
			(0.0382)
Constant	0.286***	0.145***	0.414**
	(0.0337)	(0.0427)	(0.161)
N	1,413	1,413	1,350
R-squared	0.011	0.054	0.079

Notes: Weighted OLS estimates of the effect of establishing a Fisheries Management Committee (FMC) on vaccination decisions for young children. Robust standard errors clustered at the village level in parentheses. ***, **, * indicates statistical significance at the 1%, 5% and 10% level respectively. Sample truncated to villages with distance to river less than 2km, children less than 24 months old and with absolute value of HAZ less than 6, and propensity score within the 1-99 percentiles of its distribution. Data on vaccination decisions and other child and household level controls from the Laos Social Indicator Survey 2011/2012. Data on village treatment status from 2011 Laos Agricultural Census. Sample size of children living in urban, rural with road and rural without road villages in model (1) is 321, 887 and 205 respectively.

Table A.6: The impact of fisheries decentralization on the nutrition of young children (without trimming the propensity score)

Dependent variable:	HAZ (1)	HAZ (2)	HAZ (3)
FMC X Rural village with no road (0 no; 1 yes)	1.209***	1.121***	0.975***
	(0.335)	(0.330)	(0.313)
FMC X Rural village with road (0 no; 1 yes)	0.390*	0.292	0.208
	(0.210)	(0.207)	(0.197)
FMC (0 no; 1 yes)	-0.298*	-0.243	-0.228
	(0.172)	(0.170)	(0.163)
Rural village with road (0 no; 1 yes)	-0.292**	-0.345***	-0.0946
	(0.115)	(0.120)	(0.119)
Rural village with no road (0 no; 1 yes)	-0.604***	-0.632***	-0.216
	(0.213)	(0.212)	(0.226)
Sex (0 female; 1 male)		-0.205**	-0.244***
		(0.0793)	(0.0837)
Child measured standing (0 no; 1 yes)		0.646***	0.709***
		(0.204)	(0.207)
Age (months)		-0.0779***	-0.0799***
		(0.00717)	(0.00728)
Mother's education: primary (0 no; 1 yes)			0.142
			(0.115)
Mother's education: secondary (0 no; 1 yes)			0.228
			(0.141)
Mother's education: higher (0 no; 1 yes)			0.101
			(0.169)
Dependence ratio			0.117
			(0.377)
Mothers age <20 at birth (0 no; 1 yes)			-0.297
			(0.185)
Mothers age 20-34 at birth (0 no; 1 yes)			-0.144
			(0.138)
Ethnicity of household head Lao (0 no; 1 yes)			0.181*
			(0.0964)
Ethnicity of household head Khmu (0 no; 1 yes)			0.0707
			(0.166)
Ethnicity of household head Hmong (0 no; 1 yes)			0.0733
			(0.165)
Birth order			-0.112*
			(0.0668)
Sex of household head (0 female; 1 male)			0.0241
			(0.157)
Household is owned by household member (0 no; 1 yes)			0.124
			(0.233)
Household has electricity (0 no; 1 yes)			0.203*
			(0.117)
Household with piped water source (0 no; 1 yes)			-0.101
			(0.129)
Household with improved sanitation (0 no; 1 yes)			0.187
			(0.114)
Positive salt iodization test (0 no; 1 yes)			-0.0119
			(0.106)
Constant	-1.043***	-0.0107	-0.430
	(0.0897)	(0.130)	(0.419)
Observations	1,616	1,616	1,549
R-squared	0.017	0.136	0.172

Notes: Weighted OLS estimates of the effect of establishing a Fisheries Management Committee (FMC) on young children’s height-for-age z-score (HAZ). Robust standard errors clustered at the village level in parentheses. ***, **, * indicates statistical significance at the 1%, 5% and 10% level respectively. Sample truncated to villages with distance to river less than 2km and children aged less than 24 months old with absolute value of HAZ less than 6.

Data on HAZ and other child and household level controls from the Laos Social Indicator Survey 2011/2012. Data on village treatment status from 2011 Laos Agricultural Census. Data on other village characteristics from 2005 Laos Population Census. Sample size of young children living in urban, rural with road and rural without road villages in model (1) is 466, 945 and 205 respectively.

Table A.7: Effect of fisheries decentralization on fish consumption

Dependent variable:	Fish consumed by household in past month		
	(1)	(2)	(3)
FMC X Rural village with road (0 no; 1 yes)	66,791*	69,643**	67,991**
	(34,039)	(33,680)	(33,671)
FMC X Rural village with no road (0 no; 1 yes)	151,278**	153,541**	155,235**
	(73,672)	(75,107)	(72,666)
FMC (0 no; 1 yes)	-26,569	-27,603	-26,151
	(28,455)	(27,974)	(27,624)
Rural village with no road (0 no; 1 yes)	-92,385**	-90,345**	-96,157**
	(35,629)	(37,746)	(38,477)
Rural village with road (0 no; 1 yes)	-26,124	-24,207	-26,880
	(17,491)	(17,870)	(18,141)
Household dependency ratio		-59,028**	-58,117**
		(23,234)	(22,790)
Sex of household head (0 female; 1 male)		53,937***	53,785***
		(19,831)	(19,781)
Agricultural land owned (ha)		2,591	2,514
		(3,584)	(3,513)
Productive assets index		823.0	669.8
		(5,019)	(5,043)
Household size		5,578*	5,450*
		(3,257)	(3,289)
Survey in the wet season (0 no; 1 yes)			-14,155
			(17,821)
Constant	223,056***	155,634***	165,680***
	(13,208)	(27,113)	(30,873)
Observations:	1,207	1,207	1,207
R-squared	0.031	0.049	0.050

Notes: Weighted OLS estimates of the effect of establishing a Fisheries Management Committee (FMC) on fish consumption. Robust standard errors clustered at the village level in parentheses. ***, **, * indicates statistical significance at the 1%, 5% and 10% level respectively. Sample truncated to villages with distance to river less than 2km, propensity score within the 1-99 percentiles. 47 outliers of fish consumption observations (identified using the hadimvo function in Stata) were excluded from the analysis. Fish consumption valued in LAK (9,583.36 LAK ≈ 1 USD). Productive assets index estimated as the first principal component of the value of productive assets owned by the household. Data on village treatment status from 2011 Laos Agricultural Census. Fish consumption data and household level controls from the 2012/2013 Lao Expenditure and Consumption Survey.

Table A.8: Effect of fisheries decentralization on fishing inputs

Dependent variable:	Time fishing by household in past 24 hours			Household owns fishing net (0 no; 1 yes)			Household owns boat (0 no; 1 yes)		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
FMC X Rural village with road (0 no; 1 yes)	0.00719	-0.0189	-0.0106	0.0963	0.128	0.109	0.105	0.0981	0.0980
	(0.477)	(0.484)	(0.485)	(0.121)	(0.116)	(0.117)	(0.115)	(0.117)	(0.117)
FMC X Rural village with no road (0 no; 1 yes)	0.555	0.570	0.561	0.102	0.121	0.140	0.272	0.256	0.257
	(0.759)	(0.763)	(0.768)	(0.165)	(0.157)	(0.132)	(0.247)	(0.246)	(0.247)
FMC (0 no; 1 yes)	0.453	0.460	0.452	0.0131	-0.00299	0.0132	-0.0755	-0.0679	-0.0678
	(0.409)	(0.406)	(0.407)	(0.0989)	(0.0944)	(0.0954)	(0.0891)	(0.0912)	(0.0909)
Rural village with no road (0 no; 1 yes)	0.220	0.116	0.144	0.202*	0.230**	0.167**	0.0978	0.116	0.116
	(0.424)	(0.433)	(0.456)	(0.113)	(0.103)	(0.0834)	(0.182)	(0.181)	(0.183)
Rural village with road (0 no; 1 yes)	0.146	0.120	0.132	0.0680	0.0819	0.0542	0.0938	0.104	0.103
	(0.283)	(0.288)	(0.293)	(0.0737)	(0.0744)	(0.0683)	(0.0799)	(0.0803)	(0.0817)
Household dependency ratio		-0.756**	-0.762**		-0.0921	-0.0793		-0.173**	-0.173**
		(0.358)	(0.361)		(0.0777)	(0.0750)		(0.0784)	(0.0782)
Sex of household head (0 female; 1 male)		0.0680	0.0672		0.247***	0.249***		0.00105	0.00106
		(0.369)	(0.370)		(0.0662)	(0.0661)		(0.0634)	(0.0632)
Agricultural land owned (ha)		0.0132	0.0136		0.000884	-1.74e-05		0.00529*	0.00529*
		(0.0210)	(0.0207)		(0.00223)	(0.00229)		(0.00301)	(0.00306)
Productive assets index		-0.168**	-0.167**		0.0539***	0.0525***		-0.00390	-0.00390
		(0.0839)	(0.0841)		(0.0172)	(0.0170)		(0.0180)	(0.0181)
Household size		0.114***	0.115***		0.0161*	0.0146*		0.000240	0.000236
		(0.0434)	(0.0439)		(0.00884)	(0.00832)		(0.00876)	(0.00875)
Survey in the wet season (0 no; 1 yes)			0.0684			-0.155***			-0.000421
			(0.222)			(0.0546)			(0.0625)
Constant	0.896***	0.494	0.448	0.487***	0.182*	0.288***	0.181***	0.215**	0.216*
	(0.253)	(0.473)	(0.487)	(0.0590)	(0.0940)	(0.0987)	(0.0637)	(0.0967)	(0.115)
Observations	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254	1,254
R-squared	0.019	0.036	0.036	0.032	0.076	0.100	0.035	0.043	0.043

Notes: Weighted OLS estimates of the effect of establishing a Fisheries Management Committee (FMC) on fishing inputs. Robust standard errors clustered at the village level in parentheses. ***, **, * indicates statistical significance at the 1%, 5% and 10% level respectively. Sample truncated to villages with distance to river less than 2km and propensity score within the 1-99 percentiles. Productive assets index estimated as the first principal component of the value of productive assets owned by the household. Data on village treatment status from 2011 Laos Agricultural Census. Dependent variables and household level controls from the 2012/2013 Lao Expenditure and Consumption Survey.