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# Natural Resource Management and Nutrition Outcomes: A Quasi-experimental Evaluation of Fisheries Decentralisation in Laos.

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Jeremy Smith (Head of the Department of Economics, University of Warwick) and Michael Ward (Head of the Department of Economics, Monash University)

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**Natural resource management and nutrition outcomes:**

**a quasi-experimental evaluation of fisheries decentralisation in Laos**

Benjamin Chipperfield*

**Abstract**

We estimate the impact of a national fisheries decentralisation policy on the nutritional status of children in Lao PDR. Using a double robust estimator that combines propensity score and OLS regression, our results show that the causal impacts of this policy are heterogeneous and driven by nutritional gains among younger children living in villages that rely more heavily on natural resources, with girls benefiting more than boys. We identify higher consumption of fish as one mechanism that explains these gains. This change is not accompanied by greater allocation of time to fishing or investment in fishing assets, allaying fears that decentralisation of fisheries management may lead to over-exploitation of local resources. Our findings show that nationally implemented decentralised natural resources management policies can improve welfare.

**Keywords**: Fisheries decentralisation; Laos; Height for age z-score

**JEL classifications**: Q22, Q28

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## 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 economic dependency of local livelihoods on natural resources (Barbier, 2006). TEEB (2009) estimate that over 1 billion people in developing countries rely on fish as an essential source of nutrition. More recent estimates suggest that freshwater fisheries in particular 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) suggest 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 government policies (Fluet-Chouinard et al., 2018), which has important consequences for their sustainability. 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).

This paper quantifies the impact of decentralising freshwater management on one important human outcome: child nutritional status. As is recognised, weak property rights create the conditions for over-exploitation of natural resources, the well-known 'tragedy of the commons' described in Hardin (1968). Two common policy prescriptions followed from Hardin's (1968) metaphor: government regulation or privatisation. Ostrom (1990) argues that the tragedy follows from the 'open access' nature of some natural resources and that communities (defined by Agrawal and Gibson (1999) as the intersection of a spatial unit, a social structure and a set of shared norms) may be more effective than traditional policy prescriptions in regulating access to the resource and promoting its sustainability. Underlying the promotion of 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 (Ostrom, 1990). 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), the lack of empirical evidence about its impact, either on the environment or the households that rely on the services it provides, raised the alarm that it was being approached as a panacea (Ostrom, Janssen, & Anderies, 2007; Young et al., 2017). This is illustrated by Evans et al. (2011), a meta-analysis of the impact of fisheries decentralisation on human wellbeing in developing countries, who conclude that a large majority of studies (83%) find insignificant impacts or no change while the remaining are almost equally divided between those that find either positive or negative impacts. The authors 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 decentralisation on any outcome, and (2) they all focused on local case studies, ignoring the potential impact of policies implemented at a national scale. Our paper contributes to this literature by addressing these two gaps in knowledge, as we use quasi-experimental methods to quantify the causal impact of a national decentralised fisheries management policy on child malnutrition.

Our data comes from Lao PDR, a landlocked country that relies heavily on the Mekong River and its tributaries as a source of ecosystem services, including fish (Emerton, 2013). As in other developing countries (Fluet-Chouinard et al. 2018), fisheries contribute heavily to the local diet, with fish providing approximately 50% of their total protein as well as essential micronutrients including vitamins A and B12, iron, and zinc (Allison & Mills, 2018; Baran, Jantunen, & Chong, 2007).

In 2009, the government of Lao PDR approved a new Fisheries Law that included the decentralisation 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 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. In its functioning, the FMC should be able to rely on the support from central and local government, 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 regulation), together with implementation costs (namely distance from administrative headquarters), played an important role in the decision of where to establish FMCs. Criteria such as these, even if not directly targeting differences in health outcomes or economic conditions, suggest that areas with FMCs may be fundamentally different from those without, in ways that matter for our analysis of impacts on child nutrition. For example, villages closer to administrative headquarters may have greater access to utility services such as electricity and piped water, both of which may lead to better nutrition outcomes. Given the potential bias introduced by program placement, areas without the program would not be an appropriate counterfactual to those with FMCs, and 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.[1] We find no evidence of an average effect of this policy on the nutritional status of children under 5 years old, measured using their height-for-age z-score (HAZ), collected as part of the 2011/2012 Lao Social Indicators Survey (LSIS). This lack of an average impact likely reflects two factors that together, work to attenuate our estimates of the impact of this policy in the population.

The first, and most obvious, is the timing of the survey used to measure human outcomes. We rely on data on human outcomes collected in 2011, shortly after the approval of the 2009 Fisheries Law. As a result, while children younger than 2 years old experienced the impacts of FMCs for most of their life, older children may have only experienced them after important growth milestones had already occurred (Victoria, 2009). Hence, one important dimension of heterogeneity that may attenuate the average estimates of the impacts of FMCs is child age, and in particular the distinction between children younger or older than 2 years old.

The second, and perhaps less obvious dimension of heterogeneity in these impacts, is the moderating effect of ex-ante economic conditions at the village level, which may determine the relative importance of fishing on diet and local livelihoods. We consider differences in local livelihoods between three strata: urban villages, and rural villages with and without roads. We would expect that isolated rural communities would rely more heavily on local food production, including local fisheries (Allison & Mills, 2018; Fluet-Chouinard et al., 2018). This is borne by our data: measured as a proportion of total expenditure on food, estimated using

[1] Other recent uses of this approach to the analysis of the impact of CBNRM policies include Khan, Alam and Islam (2012), Haque and Dey (2016), Oldekop, Sims, Karna, Whittingham and Agrawal (2019), Pailler, Naidoo, Burgess, Freeman and Fisher (2015) and Riehl, Zerriffi and Naidoo (2015).

data from the 2012/2013 Laos Expenditure and Consumption Survey in villages without FMCs, households in rural villages without roads are more reliant on fish in their diet (fish constitutes 25% of total food consumption) compared with rural areas with roads and urban areas (20% and 16% respectively). Given these differences, rural areas without roads would be expected to experience the largest impacts from the establishment of FMCs.

A heterogeneity analysis of the impact of FMCs that accounts for these two moderators allows for two conclusions: decentralised 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: FMCs increase the HAZ of young children living in rural areas without road access by 1.29-1.37 standard deviations (SD) depending on the model specification. We also find that young girls benefit most from these changes, suggesting that the alleviation of constraints in access to food matters most to those that are typically discriminated against. A placebo analysis of the effect of FMCs on vaccination decisions (a health outcome measured at individual level in these same communities) rules out alternative explanations of these results.

We also find support for increased fisheries productivity as one mechanism underlying these impacts. A similar analysis of heterogeneous impacts of establishing FMCs shows that households in rural villages significantly increased fish consumption, an effect that is particularly pronounced in those that have no access to roads. 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**

Ideally, we would estimate the impact of fisheries decentralisation 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). As it is well known, this equation formalises the fundamental problem of impact evaluation, as half of the potential nutrition outcomes are missing (Holland, 1986).

Given this missingness problem, we can estimate the average treatment effect 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 decentralised 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 long and covers a variety of contexts, ranging 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, 2012; Mezzatesta, Newburn, & Woodward, 2013), decentralised forest management (Oldekop et al., 2019) and, closer to the topic of this paper, the effect of decentralised fisheries management (Haque & Dey, 2016; Khan et al., 2012).

Because FMCs were formed at village level, the propensity score is estimated using confounders also measured at that level. As a result, estimating the average treatment effect 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 due to differences in child characteristics and their household environment, which were not included in equation (3). As a result, it is unlikely that the difference estimated in equation (4) could have a causal interpretation.

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

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

where weights are constructed using the estimated propensity score, according to the expression (Nichols, 2008):

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

where probability weights are used to make treatment and control groups similar with respect to village observable characteristics, allowing us to eliminate the selection bias that arises from non-random treatment placement at the village level, and the inclusion of $\boldsymbol{Z}_{iv}$, a vector of 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 $\beta_1$ is our coefficient of interest and captures the effect of fisheries decentralisation 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, 2005), 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).

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 seen as both substantially 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.

Although both bounding estimates (Rosenbaum, 2007) and placebo analyses (Imbens & Rubin, 2015) can potentially be used, ultimately the credibility of any causal statement will depend on the ability to explain why seemingly identical observations received different treatment status (which is likely program specific). In the next section we will argue that the bureaucratic constraints underlying the decentralisation of fisheries management in Lao PDR (in particular, funding and personnel constraints) plausibly created variability in treatment status that, conditional on observable characteristics of villages, is as if random.

**3. Data**

We use three datasets, collected almost simultaneously in the period 2011/2013 to quantify the impact of decentralising 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 plausibly non-random decision to establish local fisheries committees.

The 2011 Laos 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%) had established an FMC, suggesting that the adoption of this policy was quite rapid.

The analysis of the placement of these committees in the territory, and in particular their distance to the closest river, confirms that their placement was not-random, as expected. Figure 1 presents the probability of FMC establishment as a function of distance to the nearest river (estimated using local polynomial regression), and visually 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. [2] As

[2] 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).

a first step in making villages with and without FMCs comparable, we excluded villages with a distance to the nearest river greater than 2km from the analysis.

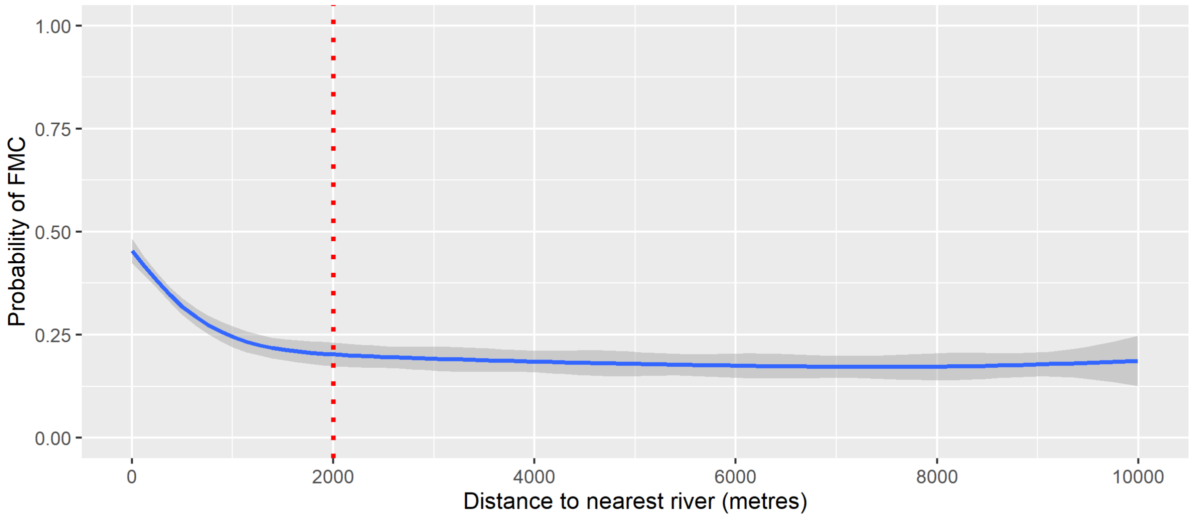


**Fig. 1: Probability of FMC conditional on village distance to nearest river**

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 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 as additional control variables when estimating the weighted OLS regression (equation (5), above).

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 exclude observations with biologically infeasible values of HAZ.[3] Children in villages with FMCs appear to be slightly more malnourished (mean of -1.534) than those without FMCs (mean of -1.510), but this difference is not significant (p-value = 0.645).

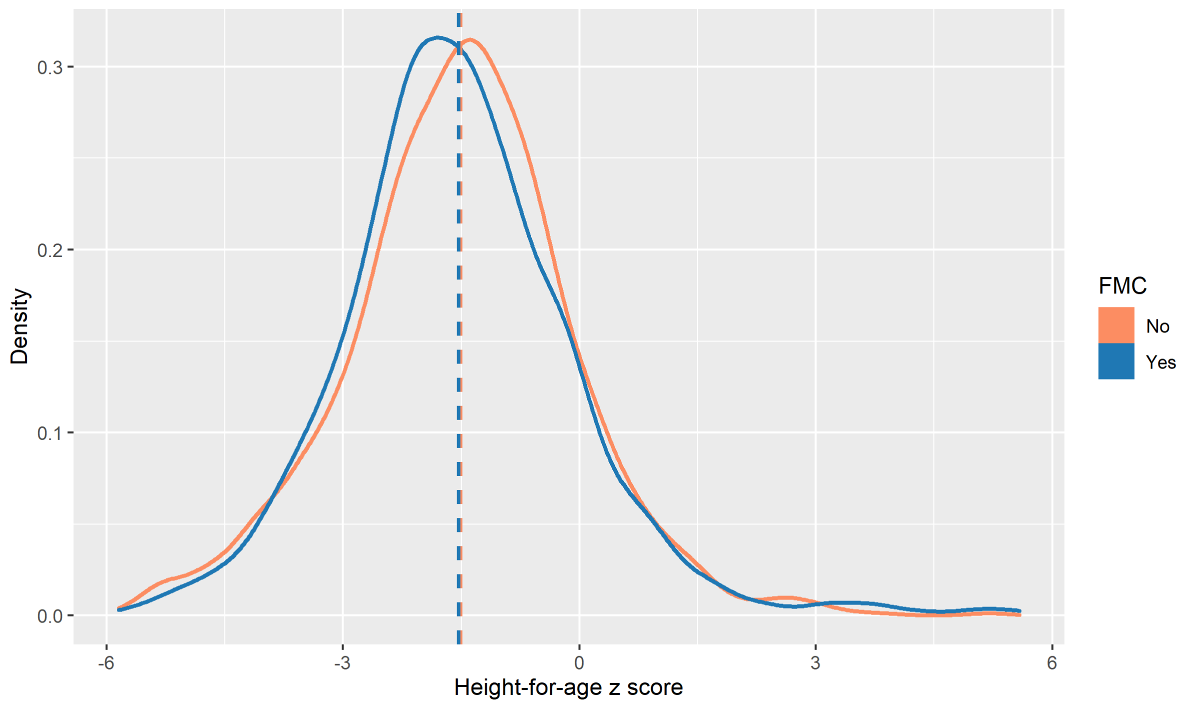


**Fig. 2: Density plot of height-for-age z score by treatment group**

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 with absolute value of HAZ less than 6.

[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).

This difference could be interpreted as the causal impact of fisheries decentralisation 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 create an FMC 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 decentralisation 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 intuitively related with the probability of establishing an FMC. As in Figure 1, we restrict the analysis to villages closer than 2km from the nearest river. 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.[4] Households in villages with FMCs are less likely to be ethnically Lao and are

[4] Ethnicity heterogeneity may be an important element of the implementation decision because people of similar ethnicities are more likely to communicate and cooperate, having similar communication styles, practices and values (Cox, Lobel, & Mcleod, 1991; Hamer et al., 2018). We measure this by constructing a Herfindahl–Hirschman Index (HHI) using the percentage of each ethnic group from the 2005 Population Census.

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.

**Table 1: Balance on village characteristics across FMC groups**

| 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) | |
| 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 living below the poverty line | 34.563 | 40.097 | -5.535*** |
| | (0.423) | (0.598) | |
| % 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 the effect of fisheries decentralisation 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 in the month of the survey than those in villages without them: on average, household fish consumption was valued at 287,683.5 Lao Kip (LAK) and 236,533.2 LAK, for households in villages with and without FMCs respectively (p-value=0.0015). As previously discussed in relation to differences in HAZ between villages with and without FMCs, differences in fish consumption cannot be interpreted as a causal effect of fisheries decentralisation, given that pre-treatment differences may be driving this discrepancy.

## 4. Results

### 4.1. Estimating the average impact of fisheries decentralisation

The establishment of FMCs took place at the national level by a bureaucratic decision-maker, likely separate from the fishers who benefit from the program. Using available village level information, the social planner likely decides where to establish FMCs based on minimising costs and maximising the relative benefits to society (which may depend on factors such as distance to river, administrative headquarters, and measures of poverty, information for which is included in the formation of our propensity score), subject to a government budget constraint for this program. This also likely explains why some villages received FMCs while others, identical on pre-treatment characteristics, did not: budgetary constraints and bureaucratic noise in estimates regarding the benefits and costs of project implementation in each village. Although we cannot prove that no significant unobserved variables exist which contribute to the FMC implementation decision and our outcome of interest, forming the propensity score on a rich set of variables from a high-quality population census dataset which likely explain the FMC implementation decision significantly increases the robustness of our estimates (Dehejia & Wahba, 2002; Smith & Todd, 2001).

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.[5] 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. Unsurprisingly, distances to nearest river, province capital and district capital all significantly explain the FMC implementation decision in the propensity score estimation, as does the prevalence of poverty.

Following Imbens (2015), we exclude the top and bottom 1% of the distribution of the estimated propensity score 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.[6] In what follows, we present weighted OLS regressions with trimming, controlling for these unbalanced variables, but our conclusions are generally robust to these decisions.[7]

[5] See Table A.1 for estimates of the propensity score.
[6] See Table A.2.
[7] Results without trimming and without controls are presented in Tables A.9 and A.10.

The average treatment effect of FMCs on HAZ, estimated using weighted OLS regression, is shown in Table 2. Model (1) is our base model. In addition to treatment status (whether an FMC is established or not, defined at village level), it controls for age and sex of the child, as well as whether the child was measured while standing. It also controls for the four village level variables unbalanced due to trimming. Model (2) includes all of the variables in model (1) as well as demographic controls, including the sex and ethnicity of the household head, and the mother's education level. Finally, model (3) includes all variables in model (2) as well as controls for household living conditions, such as access to electricity or piped water. As shown in Table 2, we find no evidence that establishing an FMC affects children's nutritional status.[8]

**Table 2: The impact of fisheries decentralisation on child nutrition**

| Dependent variable: | HAZ<br>(1) | HAZ<br>(2) | HAZ<br>(3) |
|---|---|---|---|
| FMC (0 no; 1 yes) | 0.125 | 0.0795 | 0.0804 |
| | (0.0774) | (0.0652) | (0.0633) |
| Sex (0 female; 1 male) | -0.160*** | -0.165*** | -0.171*** |
| | (0.0570) | (0.0557) | (0.0564) |
| Child measured standing (0 no; 1 yes) | 0.476*** | 0.476*** | 0.485*** |
| | (0.120) | (0.115) | (0.114) |
| Age (months) | -0.0352*** | -0.0334*** | -0.0338*** |
| | (0.00358) | (0.00347) | (0.00345) |
| % of households with farmland | 0.00458** | 0.00445*** | 0.00432*** |
| | (0.00179) | (0.00135) | (0.00150) |
| % population unemployed | 0.00748** | 0.00488 | 0.00393 |
| | (0.00365) | (0.00333) | (0.00340) |
| % of population with main activity non-farm sector | 0.00785*** | 0.00369* | 0.00236 |
| | (0.00278) | (0.00197) | (0.00213) |
| Village with water supply (0 no; 1 yes) | -0.156 | -0.108 | -0.0891 |
| | (0.236) | (0.174) | (0.175) |
| Demographic controls | No | Yes | Yes |
| Living conditions controls | No | No | Yes |
| N | 3,007 | 3,007 | 3,007 |
| R-squared | 0.103 | 0.153 | 0.158 |

Notes: Weighted OLS estimates of the effect of establishing a Fisheries Management Committee (FMC) on 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 with absolute value of HAZ less than 6 and propensity score within the 1-99 percentiles of its distribution. Data on child nutritional status 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. See Table A.3 for full results.

[8] See Table A.3 for full results.

### 4.2. Exploring impact heterogeneity

This initial result is perhaps unsurprising, for two reasons. Firstly, it is known that rural communities 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 communities are then more likely to experience the impact from changes in fisheries management, if any. In contrast we would expect that such effects would be attenuated for children living in urban areas, given access to alternative food items (for example, through access to more diversified markets). Secondly, the timing of this policy will likely also matter. Although the establishment of FMCs followed the approval of the 2009 Fisheries Law, and our data on child anthropometrics was recorded barely 2 years after, the results in Table 2 do not reflect the inherent heterogeneity in children's exposure to fisheries decentralisation. Whereas children younger than 2 years old at the time of the LSIS data collection were exposed to the program during crucial stages of development (Victoria, 2009), older children only experienced its impacts when their health status was likely already largely determined, and they were less likely to catch-up from any previous health injuries.

In order to explore these possible sources of heterogeneity we estimate the following weighted OLS regressions:

$$H_{iv} = \alpha + \beta_1 D_v + \beta_2 RuralRoad_v + \beta_3 RuralNoRoad_v + \beta_4 RuralRoad_v * D_v + \beta_5 RuralNoRoad_v * D_v + \boldsymbol{\theta}\, \boldsymbol{Z}_{iv} + \varepsilon_{iv} \qquad (6)$$

$$H_{iv} = \alpha + \beta_1 D_v + \beta_2 RuralRoad_v + \beta_3 RuralNoRoad_v + \beta_4 Young_{iv} + \beta_5 RuralRoad_v * D_v + \beta_6 RuralNoRoad_v * D_v + \beta_7 Young_{iv} * D_v + \beta_8 Young_{iv} * RuralRoad_v + \beta_9 Young_{iv} * RuralNoRoad_v + \beta_{10} Young_{iv} * RuralRoad_v * D_v + \beta_{11} Young_{iv} * RuralNoRoad_v * D_v + \boldsymbol{\theta}\, \boldsymbol{Z}_{iv} + \varepsilon_{iv} \qquad (7)$$

where $RuralRoad_v$ and $RuralNoRoad_v$ are dummy variables which take the value of 1 if the village is in a rural area with or without roads respectively, and $Young_{iv}$ is a dummy variable which takes the value of 1 if the child is less than 2 years old. In equation (6), $\beta_4$ and $\beta_5$ capture the effect of FMCs on the nutritional status of children in rural areas with and without roads respectively (compared with similar children in urban villages). In equation (7), $\beta_{10}$ and $\beta_{11}$ capture the effect of FMCs on the nutritional status of young children in rural areas with or without roads respectively (compared with older children living in those same villages). Figure 3, panel A, presents estimates for $\beta_4$ and $\beta_5$ from equation (6) and associated confidence intervals (thick and thin line representing 90% and 95% confidence respectively) for each of the three model specifications defined in Table 2.[9]

Two conclusions emerge from these results. Firstly, fisheries decentralisation only had an impact on children living in rural areas without road access. These estimates are always significant at the 10% level and, in the case of the base model (corresponding to model (1) in Table 2), at the 5% level. The second conclusion is that the magnitude of this effect is relatively large: between 0.401-0.606 SD for models (3) and (1) respectively. This result is consistent with the interpretation that rural areas with no roads have the highest dependence on fisheries.

Panel B in Figure 3 presents the effect of fisheries decentralisation on HAZ when we account for both sources of impact heterogeneity discussed above (estimates for $\beta_{10}$ and $\beta_{11}$ from equation (7)).[10] Again, we find no impact of fisheries decentralisation in rural areas with road access, even when considering the possible moderating effect of children's age. However, the estimates of the impact of this policy on children under 2 years old in villages without access to roads is both much larger than the estimates presented in panel A and precisely estimated (all estimates significant at the 1% level). The effects are economically important:

[9] See Table A.4 for full results.
[10] See Table A.5 for full results.

fisheries decentralisation led to average gains in HAZ between 1.29-1.37 SD for models (3) and (1) respectively. To put the magnitude of these results into perspective, a young child with a HAZ $= -3$, defined as severely stunted, in a rural village with no road access would no longer be stunted, with a HAZ $< -2$, if exposed to the FMC program (World Health Organization and the United Nations Children's Fund, 2019).

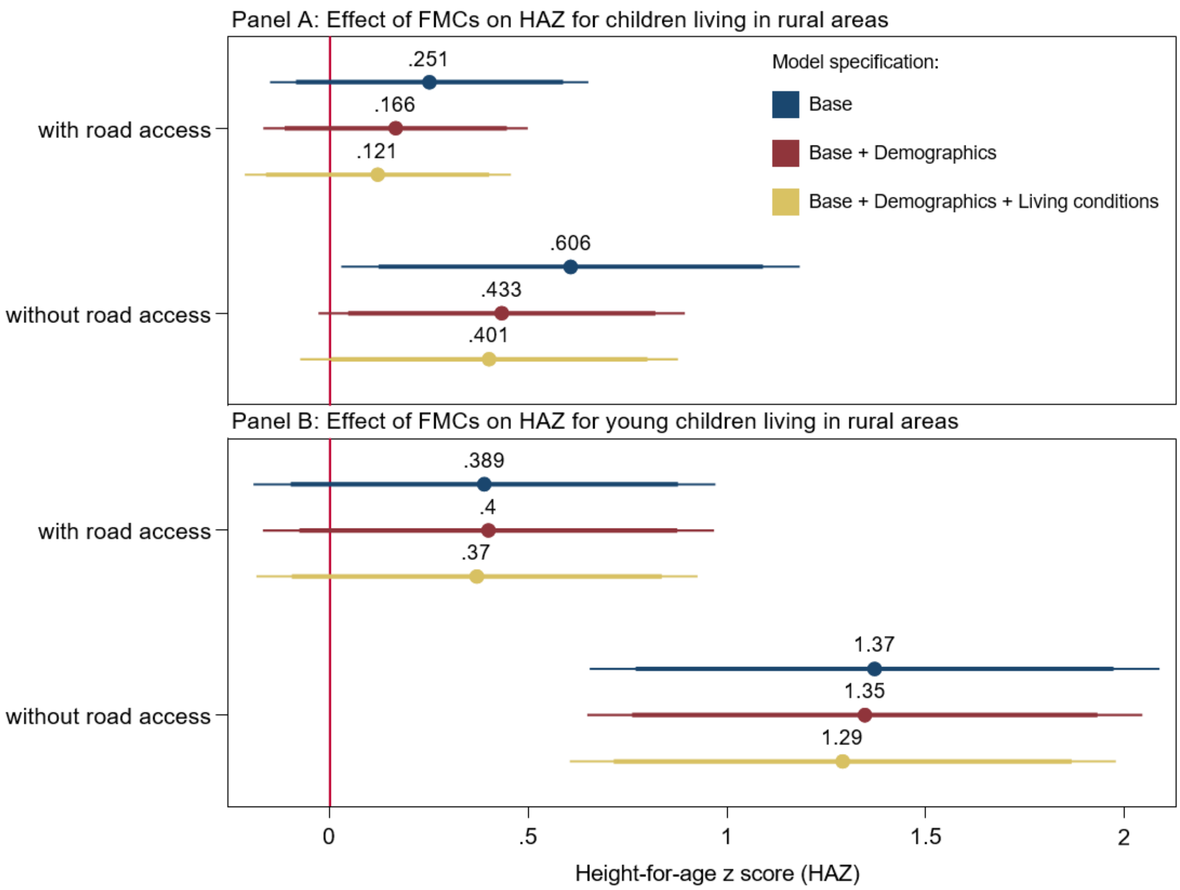


**Fig. 3: Heterogenous effects of fisheries decentralisation on children's HAZ**

Notes: Weighted OLS estimates of the heterogenous effects of establishing a Fisheries Management Committee (FMC) on children's height-for-age z-score (HAZ). Robust standard errors clustered at the village level. Points represent the associated coefficient estimate for the respective subsample category. The thick and thin lines represent the 90% and 95% confidence intervals respectively. Sample truncated to villages with distance to river less than 2km, children with absolute value of HAZ less than 6 and propensity score within the 1-99 percentiles of its distribution. Data on child nutritional status 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. See Table A.4 and A.5 for full results.

Economic environment and age are not the only possible moderators of the impact of changes in the management of natural resources. Among the many possible others, we focus on the sex of the child, given the persistent suspicion that girls are discriminated against (Borooah, 2004; Ndiku, Jaceldo-Siegl, Singh, & Sabaté, 2011). Figure 4 presents the estimates of equation (7) when we split the sample between boys (panel A) and girls (panel B).[11]

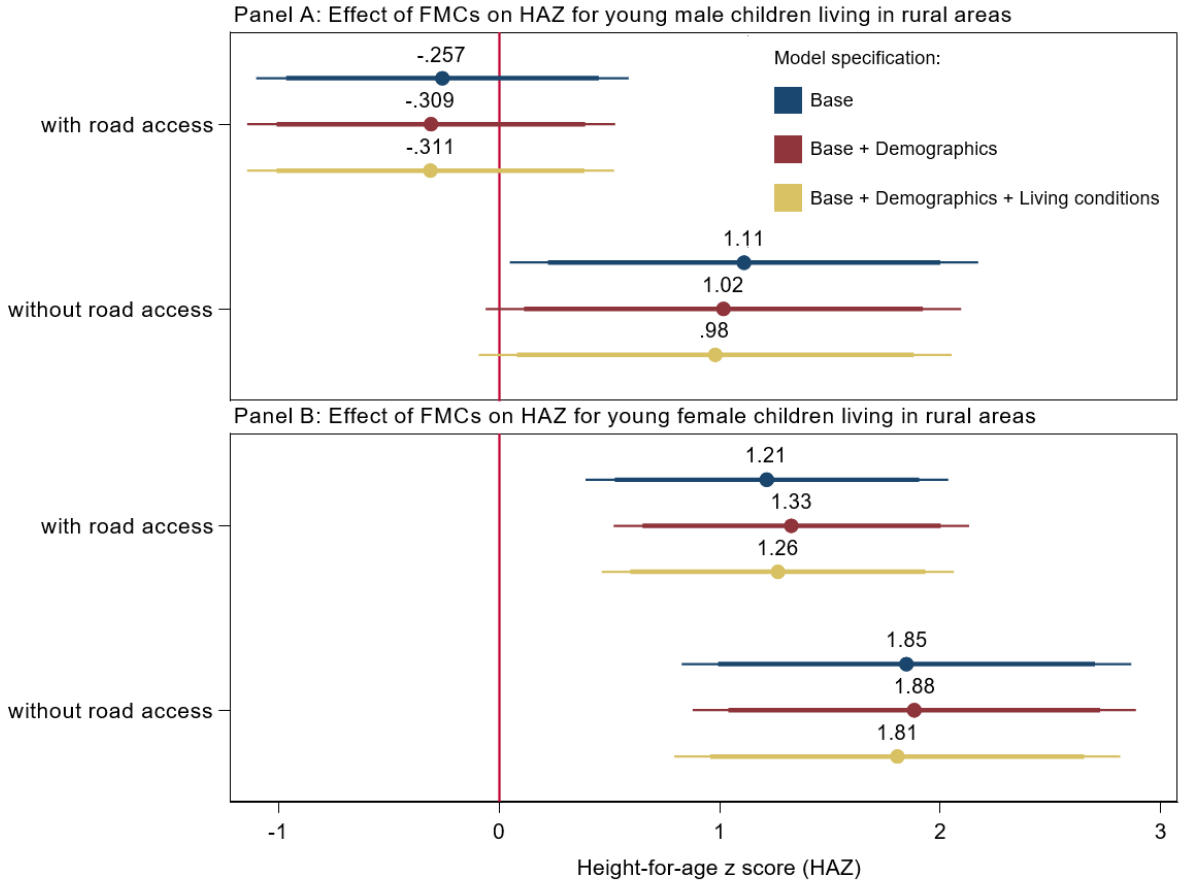


**Fig. 4: The moderating effect of children's sex on the impact of fisheries decentralisation on nutrition outcomes**

Notes: Weighted OLS estimates of the heterogenous effects of establishing a Fisheries Management Committee (FMC) on children's height-for-age z-score (HAZ). Panel A restricts the sample to male children and Panel B restricts the sample to female children. Robust standard errors clustered at the village level. Points represent the associated coefficient estimate for the respective subsample category. The thick and thin lines represent the 90% and 95% confidence intervals respectively. Sample truncated to villages with distance to river less than 2km, children with absolute value of HAZ less than 6 and propensity score within the 1-99 percentiles of its distribution. Data on child nutritional status 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. See Table A.6 and A.7 for full results.

[11] See Tables A.6 and A.7 for full results.

The main conclusion is that young girls benefit more from fisheries decentralisation than young boys: average gains in HAZ for girls are both large, ranging between 1.21-1.33 SD in villages with roads and between 1.81-1.85 SD in villages without roads, and precisely estimated in all models (significant at the 1% level), while average effects for boys are insignificant in villages with roads and between 0.98-1.11 SD in villages without roads, significant at the 5% level in model (1) and decreasing to the 10% level after the inclusion of controls.

One possible explanation for this difference is the existence of discrimination in the household allocation of food that privileges access to scarce food towards men and boys. It is then possible that, if changes in fisheries management improve access to food (as we will show in Section 4.5), girls will benefit disproportionately from any alleviation of the resource constraints.

### 4.3. Placebo test

One possible alternative explanation for the results presented above is that villages where FMCs were established simply differed in other determinants of potential health outcomes. Because some of these determinants are likely unobserved, we cannot directly rule out this explanation. We can, however, test the effect of fisheries decentralisation on health decisions that plausibly reflect any unobserved determinant of health outcomes but are less plausibly linked with fisheries management. One such outcome, for which we have data, is child vaccination: rejecting the null hypothesis of no effect of fisheries decentralisation 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 potential health outcomes that can potentially explain our results.

Table 3 presents the weighted OLS estimates regression of the effect of FMCs on child vaccination decisions, a dummy variable that is equal to 1 if the child received any vaccine, using the same specification as equation (7).[12] Regardless of the specification, FMCs have no significant impact on the rate of vaccination, suggesting that unobserved confounders of potential health outcomes are not driving the results discussed previously.

[12] See Table A.8 for full results.

## Table 3: Effect of fisheries decentralisation on vaccination decisions

| Dependent variable: | Child received any vaccination (0 no; 1 yes) | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| FMC (0 no; 1 yes) | -0.0266 | -0.0219 | -0.0414 |
| | (0.0764) | (0.0797) | (0.0785) |
| Rural village, with road (0 no; 1 yes) | -0.0384 | -0.0416 | -0.0601 |
| | (0.0616) | (0.0621) | (0.0654) |
| Rural village, with no road (0 no; 1 yes) | 0.0121 | 0.00819 | -0.0388 |
| | (0.0853) | (0.0852) | (0.0907) |
| Child under the age of 2 (0 no; 1 yes) | -0.0920 | -0.0901 | -0.0852 |
| | (0.0566) | (0.0577) | (0.0566) |
| FMC X rural village, with road (0 no; 1 yes) | 0.0272 | 0.0232 | 0.0426 |
| | (0.0941) | (0.0968) | (0.0960) |
| FMC X rural village, with no road (0 no; 1 yes) | -0.0335 | -0.0414 | -0.0358 |
| | (0.143) | (0.146) | (0.147) |
| FMC X child under the age of 2 (0 no; 1 yes) | 0.139 | 0.142 | 0.143 |
| | (0.0900) | (0.0935) | (0.0898) |
| Rural village, with road X child under the age of 2 (0 no; 1 yes) | 0.0169 | 0.0181 | 0.0184 |
| | (0.0571) | (0.0581) | (0.0575) |
| Rural village, with no road X child under the age of 2 | -0.0813 | -0.0773 | -0.0832 |
| (0 no; 1 yes) | (0.0774) | (0.0781) | (0.0762) |
| FMC X rural village, with road X child under the age of 2 | -0.102 | -0.102 | -0.102 |
| (0 no; 1 yes) | (0.106) | (0.110) | (0.107) |
| FMC X rural village, with no road X child under the age of 2 | 0.112 | 0.109 | 0.126 |
| (0 no; 1 yes) | (0.136) | (0.137) | (0.136) |
| Sex (0 female; 1 male) | 0.00432 | 0.00851 | 0.0100 |
| | (0.0209) | (0.0204) | (0.0202) |
| Age (months) | 0.00559*** | 0.00559*** | 0.00580*** |
| | (0.00113) | (0.00110) | (0.00110) |
| % of households with farmland | 0.000855 | 0.000865 | 0.000770 |
| | (0.000943) | (0.000919) | (0.000845) |
| % population unemployed | -0.00296** | -0.00249* | -0.00245 |
| | (0.00149) | (0.00148) | (0.00149) |
| % of population with main activity non-farm sector | -0.000777 | -0.000588 | -0.000320 |
| | (0.00111) | (0.00111) | (0.00111) |
| Village with water supply (0 no; 1 yes) | 0.0545 | 0.0555 | 0.0673 |
| | (0.0752) | (0.0745) | (0.0791) |
| Demographic controls | No | Yes | Yes |
| Living conditions controls | No | No | Yes |
| N | 3,007 | 3,007 | 3,007 |
| R-squared | 0.067 | 0.074 | 0.087 |

Notes: Weighted OLS estimates of the effect of establishing a Fisheries Management Committee (FMC) on vaccination decisions. 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 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. Data on other village characteristics from 2005 Laos Population Census.

### 4.4. Mechanisms

We hypothesise that increases in fish consumption is one mechanism through which fisheries decentralisation 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 (6) 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).[13] Table 4 presents these estimates.

Model (1) finds a positive effect of FMCs on the value of household fish consumption at 69,183 LAK, significant at the 5% level. The introduction of controls reduces the significance of this effect to the 10% level; however, the magnitudes remain similar at 69,374 and 67,706 LAK for models (2) and (3) respectively. For households residing in rural areas without a road, the effect size of FMCs on fish consumption is approximately doubled: 147,523, 146,099 and 148,630 LAK for models (1), (2) and (3) respectively. These effects are significant at the 10% level for models (1) and (2) and increase to the 5% level after the inclusion of the seasonality component in model (3). This difference in magnitude between rural areas with and without a road reflects our findings in Figures 3 and 4 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.

[13] At the time of this study 9,583.36 LAK was worth approximately 1 US dollar (USD).

**Table 4: Effect of fisheries decentralisation on fish consumption**

| Dependent variable: | Fish consumed by household in past month | | |
|---|---|---|---|
| | (1) | (2) | (3) |
| FMC (0 no; 1 yes) | -27,423 | -26,443 | -24,975 |
| | (29,395) | (29,734) | (29,216) |
| Rural village, with road (0 no; 1 yes) | -27,761 | -24,942 | -28,043 |
| | (17,519) | (17,569) | (17,857) |
| Rural village, with no road (0 no; 1 yes) | -92,671** | -87,807** | -94,439** |
| | (35,629) | (35,283) | (36,137) |
| FMC X rural village, with road (0 no; 1 yes) | 69,183** | 69,374* | 67,706* |
| | (34,818) | (35,342) | (35,141) |
| FMC X rural village, with no road (0 no; 1 yes) | 147,523* | 146,099* | 148,630** |
| | (74,665) | (74,996) | (72,135) |
| Dependency ratio | | -45,781* | -44,804* |
| | | (24,371) | (23,867) |
| Sex of household head (0 female; 1 male) | | -43,959** | -44,127** |
| | | (19,339) | (19,313) |
| Productive assets index | | 1,638 | 1,443 |
| | | (4,716) | (4,812) |
| Agricultural land owned (ha) | | 2,172 | 2,069 |
| | | (4,246) | (4,142) |
| Survey in the wet season (0 no; 1 yes) | | | -16,074 |
| | | | (17,655) |
| Constant | 223,342*** | 277,527*** | 288,248*** |
| | (13,204) | (25,873) | (29,090) |
| Observations: | 1187 | 1187 | 1187 |
| R-squared | 0.032 | 0.041 | 0.044 |

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 and propensity score within the 1-99 percentiles. 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.

One possible concern with this result is that it could indicate that after decentralisation, households are simply exploring the resource in a much more intensive way, perhaps because other regulations, established at a non-local level, are eliminated or 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 decentralisation 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 5 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 4, this suggests that fisheries decentralisation 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 decentralisation policy (Haque & Dey, 2016; Khan et al., 2012).

**Table 5: Effect of fisheries decentralisation 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 (0 no; 1 yes) | 0.186 | 0.204 | 0.192 | 0.0131 | 0.00652 | 0.0228 | -0.0755 | -0.0686 | -0.0686 |
| | (0.375) | (0.374) | (0.372) | (0.0989) | (0.0986) | (0.102) | (0.0891) | (0.0915) | (0.0912) |
| Rural village, with road (0 no; 1 yes) | 0.0787 | 0.0984 | 0.120 | 0.0680 | 0.0761 | 0.0470 | 0.0938 | 0.104 | 0.104 |
| | (0.277) | (0.276) | (0.279) | (0.0737) | (0.0733) | (0.0676) | (0.0799) | (0.0803) | (0.0816) |
| Rural village, with no road (0 no; 1 yes) | 0.151 | 0.203 | 0.251 | 0.202* | 0.204* | 0.138 | 0.0978 | 0.118 | 0.118 |
| | (0.744) | (0.728) | (0.740) | (0.113) | (0.107) | (0.0847) | (0.182) | (0.181) | (0.182) |
| FMC X rural village, with road (0 no; 1 yes) | 0.157 | 0.142 | 0.154 | 0.0963 | 0.105 | 0.0860 | 0.105 | 0.0996 | 0.0996 |
| | (0.440) | (0.442) | (0.441) | (0.121) | (0.120) | (0.123) | (0.115) | (0.117) | (0.117) |
| FMC X rural village, with no road (0 no; 1 yes) | 0.859 | 0.812 | 0.795 | 0.102 | 0.116 | 0.137 | 0.272 | 0.257 | 0.257 |
| | (0.744) | (0.728) | (0.740) | (0.165) | (0.162) | (0.137) | (0.247) | (0.246) | (0.246) |
| Dependency ratio | | -0.348 | -0.356 | | -0.0685 | -0.0591 | | -0.170** | -0.170** |
| | | (0.298) | (0.298) | | (0.0742) | (0.0712) | | (0.0770) | (0.0770) |
| Sex of household head (0 female; 1 male) | | -0.0487 | -0.0448 | | -0.267*** | -0.271*** | | -0.0103 | -0.0103 |
| | | (0.254) | (0.254) | | (0.0629) | (0.0625) | | (0.0667) | (0.0663) |
| Productive assets index | | -0.0411 | -0.0430 | | | | | | |
| | | (0.0766) | (0.0771) | | | | | | |
| Agricultural land owned (ha) | | 0.0148 | 0.0155 | | -0.000591 | -0.00159 | | 0.00525* | 0.00524* |
| | | (0.0201) | (0.0198) | | (0.00337) | (0.00338) | | (0.00292) | (0.00296) |
| Survey in the wet season (0 no; 1 yes) | | | 0.116 | | | -0.162*** | | | -0.000262 |
| | | | (0.204) | | | (0.0564) | | | (0.0623) |
| Constant | 0.898*** | 1.015** | 0.936** | 0.487*** | 0.784*** | 0.894*** | 0.181*** | 0.227** | 0.227** |
| | (0.254) | (0.399) | (0.412) | (0.0590) | (0.0882) | (0.0901) | (0.0637) | (0.0957) | (0.0997) |
| Observations | 1224 | 1224 | 1224 | 1224 | 1224 | 1224 | 1224 | 1224 | 1224 |
| R-squared | 0.022 | 0.025 | 0.026 | 0.032 | 0.049 | 0.076 | 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.

## 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 decentralisation is used as one possible solution to the 'tragedy of the commons'.

This study evaluates the impact of fisheries decentralisation, 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 decentralisation, 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 decentralise 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 decentralisation decreases child malnutrition, although these results are heterogenous and 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. Furthermore, we find that young girls are the primary beneficiaries of these effects. We rule out the alternative explanations of these results, where nutritional gains are driven by unmeasured confounders of potential health outcomes, by estimating the effect of fisheries decentralisation on child vaccination decisions. We find no support for that relation. Using data from an almost contemporaneous nationally representative expenditure and consumption survey, we find that fisheries decentralisation 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 decentralisation 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 decentralisation. We evaluated the impact of this policy shortly after its implementation. 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 decentralisation. 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 that 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 decentralisation 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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