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project

Improving food security in the northern uplands of Lao PDR: identifying drivers and overcoming barriers

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1 Acknowledgments

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2 Executive summary

This project was motivated by a puzzle: why is it that, in a context of long running, sustained economic growth such as the one that characterises Lao PDR in the last 20 years, food insecurity and malnutrition remain stubbornly persistent? Addressing this puzzle motivated the search for practical ways to reduce food insecurity, which proceeded in two steps.

The first step involved an examination of the drivers of food insecurity. This involved the analysis of existent consumption and health data, collected through nationally representative surveys, at household level (LECS and LSIS, respectively), complemented by the collection and analysis of own household data in two provinces (Luang Prabang and Xieng Khuang). This analysis led to the following conclusions:

1) The microeconomic data supports a role for increased income in reducing food insecurity for households living in villages with access to year-round roads, but not for those households who lack access to such infrastructure and where, correspondingly, the importance of food insecurity assumes a much more pronounced seasonal aspect.

2) Factors such as shocks (droughts) or post-harvest losses (due to pests) are important determinants of food insecurity at household level.

3) Similarly, and even when accounting for household wealth, food insecurity seems to be driven by how decisions are made within the household (including women's agency) and behavioural constraints (including self-control).

These three conclusions guided the participatory selection and definition of potential solutions to the constraints identified. In a second step, the project defined and experimentally evaluated the impact of those potential solutions. This step led to the following conclusions:

4) It seems feasible to reduce grain losses due to rodent damage, both pre- and post-harvest, by creating incentives that allow households to overcome the coordination problems at the root of the problem – either prizes (piloted during the dry season) or by training cooperation (piloted during the wet season). In both cases, the pilot interventions were, by design, low-cost and required little or no specialised human resources. The estimated BCR is, in both cases, fairly high, and preliminary investigation of willingness to pay for such interventions suggest that they are financially sustainable.

5) Devolving the decision about training priorities to communities, an example of community-driven development, seemed to be particularly effective in terms of promoting the adoption of new technologies among smallholders, an important element of broad-based economic growth. In addition, such initiative seems to have positive effects in terms of creating "social capital". Extension priorities naturally reflected the private economic opportunities in place in the region, largely focusing on the production and management of large livestock, with meaningful impacts in terms of adoption of technologies (vaccines, improved pasture).

6) Without substantial improvements in the design of insurance products, that may lower their cost, or large subsidies, it seems unlikely that index insurance against drought may be effective in reducing the importance of covariate production shocks.

7) Cognitive capacity seems to predict a wide variety of behaviours that are of interest for policy makers interested in agricultural development, including the adoption of vaccines against foot-and-mouth disease, market orientation and marketing behaviour, and perceived vulnerability to food insecurity. Developing and

evaluating interventions that address these constraints remains an open and, hopefully active, area of research.

3 Background

Food security is a complex issue in any context. The Lao definition of food security, which closely follows the one adopted at the 1996 World Food Summit, is “to assure enough food and foodstuffs for every person at any time, both in material and economic aspects, with increasing demand on nutritional quality, hygiene and balance so as to improve health and enable normal development and efficient work” (NAPP, 2000).

The central policy issue surrounding food security in Lao PDR is that, despite impressive economic growth (averaging 7-8% per year since the early 2000s) and large reductions in poverty rates, the prevalence of food insecurity remained largely unchanged. An analysis by the Lao Statistical Authorities of the two most recent rounds of the Laos Expenditure and Consumption Survey (LECS) found little change in the percentage of population that was food insecure between 2002 (23%) and 2008 (22%) (LSB, 2012). Our own analysis of an additional round of this data confirms that the problem persisted into the 2010s: in 2012, despite an additional five years of economic growth, 20% of the population remained food insecure.

The concern about widespread food insecurity in the midst of poverty reduction was reinforced by the analysis of data on nutritional status. The Comprehensive Food Security and Vulnerability Analysis (CFSVA), conducted by the World Food Program in 2007 (WFP, 2007), concluded that:

- Every second child in the rural areas is chronically malnourished;
- Chronic malnutrition was as high in 2006 as in 1996, after a relatively long period of sustained rapid growth;
- Two thirds of the rural households have a livelihood portfolio that puts them at risk of becoming food insecure should one or more shocks occur in a given year.

Regionally, much of the focus on the importance of food insecurity has been on the Northern part of the country, particularly the upland areas. NAFRI reports that rice self-sufficiency rate (a sensitive indicator of food security among policy makers, even if with obvious deficiencies with respect to the official definition) in the Northern provinces in 2002 ranged from 73% in Xieng Khuang to 46% in Oudomxay (NAFRI, 2005). Other measures of food security, such as used by WFP (2007), lead to a similar conclusion: food insecurity is concentrated among minority ethnic groups, mostly living in the Northern Highlands (but also in the Central and Southern Highlands).

This lack of relation between economic growth and food security, and its apparent regional concentration in the north of the country, is the policy issue that motivated this research project. Addressing that concern required an early recognition that the drivers of food insecurity were largely unknown. Also unknown was how policy priorities directed at promoting commercial agriculture would affect (in positive or negative ways) the traditional food security strategies adopted by smallholders. As a result of these gaps in knowledge, it was difficult to define interventions that “work”, that is, that link economic development with improvements in food security.

The dearth of evidence explaining the lack of relation between economic growth and improvements in food security, particularly in the Northern Uplands, was widely recognised. For example, NAFRI summarised the conclusions from the recent Northern Uplands Rice-based Farming Systems (NURiFaR) project stating that “the subject is complex and further research is needed for more precise development actions” (NAFRI (2013), Foppes, Keokanoe, Chanthavong, Chitpanya and

Phengkhammy (2011)). This need was similarly identified during the 2012 ACIAR Laos Country Consultation. More concretely, and from the onset of this research project, we identified three knowledge gaps that required further analysis before concrete proposals to address the main aim of this project could be suggested

The first knowledge gap*: Little is known about why food insecurity remains problematic in some areas or for some sub-populations despite the general improvements in living standards across Lao PDR.* For example, the analysis presented in WFP (2007) was based on data specifically collected to quantify and analyse food insecurity but relied on a single survey, collected in one specific period. As such, it cannot address questions about the dynamics of food security or seasonality, and can only make weak inferences about vulnerability. These shortcomings limit the analysis of the causes of food insecurity and, correspondingly, the policy guidance that it can provide. For example, the promotion of home gardens, to address lack of dietary diversity, is directed to all rural households, although it is far from clear that all suffer from such problem.

The second knowledge gap*: Little is known about the impacts on traditional food production strategies due to increased smallholders' engagement in commercial agriculture, a central component of current development strategy of MAF.* Although there are general conceptual frameworks to address the links between food insecurity and market engagement (see, for example, von Braun and Kennedy (1994)), in the case of Lao PDR the supporting evidence of the importance of such links is purely anecdotal, as noted by Wright (2009). Repeatedly mentioned examples include

i) the effect of introduction of corn on soil erosion,
ii) the unsustainable exploitation of non-timber forest products as a result of new export markets
iii) the inequitable nature of the modalities of contract agriculture being promoted.

However, and despite the summary analysis presented in Fullbrook (2007), none of these examples are backed by systematic evidence regarding the effects on food security. With respect to the different forms that commercial agriculture can manifest itself (Wright 2009), this knowledge gap is particularly important for the cases of (i) smallholders' response to new opportunities (by planting larger areas of existing crops or devoting resources to new crops, livestock or the collection of non-timber forest products) and (ii) smallholders engaging in contract farming. The effects of a third form of commercial agriculture, land concessions, are simultaneously easier to infer (given what is known about land policies in Lao PDR) and harder to study (given the lack of easy access to data on the extent of concessions -see, however, Schonweger, Heiniman, Lu, Thalongsengchanh (2012)).

The third knowledge gap: *While numerous R&D projects focus on aspects of rural development in Lao PDR, there is no systematic evidence on the impact of these interventions in addressing food insecurity.* Generally speaking, food security was not a direct objective in these projects. Rather, most projects aimed to increase income, with the implicit assumption that such increase would translate into improvements in food consumption and nutritional status.

Understanding under which conditions such an assumption is valid is an important guideline for future work. However, the possibility to learn from such interventions is limited by the fact that the majority of evaluations of these projects did not define a counterfactual. As a result, the attribution of any impacts to the functioning of the project is problematic. These are not comments specific to Lao PDR, and to know "what works" in ensuring that agricultural development leads to improvements in food security, nutrition and health is an area of active research (see, for example, Webb

(2012, 2013), Hawkes and Ruel (2006), Dube, Pingali and Webb (2012)). Unfortunately, policy makers and practitioners are left with little guidance regarding what can be done in the most cost-effective way to address food insecurity.

The project approached these three knowledge gaps by using the analytical framework adopted by the FAO-Lao Food Insecurity and Vulnerability Information and Mapping Systems (FIVIMS) Program (FAO, 2008) to conceptualise food security. Similar to other representations, it bases food security on four pillars (availability, access, stability and utilization) and lists a variety of drivers that, at different levels, determine the degree of vulnerability to food insecurity of an individual, a household, the food system or a society. Although our primary focus was food security at household level, this framework also makes clear that households do not exist in a vacuum, and consideration needs to be given to their physical and institutional environment, including markets and the policy context in which they operate. Most directly, we used this framework as a way to organize the debate on what determines food security (the relative importance of its determinants and possible interactions) and, consequently, help in the identification of entry points for support to strengthened livelihoods, household food security and nutrition.

4 Objectives

The research strategy that we proposed addressed the knowledge gaps identified above by asking two research questions:

- **RQ1: What drives food security status in the Northern Uplands of Lao PDR?**

Key issues addressed through this research question are: the importance of persistent and transitory food insecurity, the relative importance of different assets (including natural capital) for agricultural production and nutrition, the functioning of markets, and the importance of shocks (and informal insurance) for food security status. Our approach to answering RQ1 led to two objectives.

Objective 1: Identify the past determinants of food security in the Northern Uplands of Lao PDR. The focus is on the identification of the drivers of household food security status, addressing the first research gap identified above.

This analysis should yield important insights into the causes of food insecurity. As such, it would suffice as a guide to interventions in a stagnant economic environment. This is unlikely to be the case in Lao PDR, given the push for commercial agriculture (see, for example, MAF (2010), is rapidly transforming the agricultural sector. How the various forms of smallholder participation in commercial agriculture impact on food security remained an open question and determined Objective 2.

Objective 2: Identify current constraints and opportunities to improvements in food security at household level in the Northern Uplands of Lao PDR. Achieving this objective requires the collection of primary data on aspects such as the natural resource base, current livelihood decisions, the structure of value chains, the organization of markets and the extent to which smallholders are integrated in these. This data was collected through a variety of approaches, in two provinces (Luang Prabang and Xiengkhuang) and systems (prioritising maize and cattle, the two most important cash agricultural activities).

The outcome of this analysis complemented the analysis of longitudinal data by contributing to a discussion of the importance of causes of food insecurity, in particular as they may relate with increased participation by smallholders in commercial agriculture.

- **RQ2: What are the impacts of interventions selected to address food insecurity in the Northern Uplands of Lao PDR?**

Key issues addressed through this research question are: the quantification of the impacts on food consumption and nutrition of the pilot intervention and the identification of the mechanisms through which improvements in food security are achieved. This research question is addressed through objective 3

Objective 3: Define, implement and evaluate pilot interventions aimed at improving food security status of households. We piloted and evaluated interventions that satisfied the following three ranking criteria: i) address the causes of food insecurity identified as most relevant, ii) are compatible with the economic rationale of targeted households and the assets they already have access to and iii) are feasible within the political and administrative constraints of Lao PDR, and as such be potentially scalable.

5 Methodology

The project was designed to sequentially answer the two research questions identified in the previous section. The answer to RQ1 provided a diagnostic of what drives food insecurity in the northern part of Lao PDR, both in the past and under more current circumstances. In practice, the team used a variety of methodological approaches to provide that diagnostic, which are listed and described in section 5.1.

Translating that diagnostic to concrete ways to "overcome barriers" required the selection of interventions that seemed, *ex-ante*, to be particularly promising and could be feasibly implemented and evaluated within the constraints of time and other resources of this project. The steps to be taken during that selection process were identified in the project proposal and its practical implementation is described in section 5.2, which also provides a short discussion of the structure of the chosen interventions.

Answering RQ2 relied on a more restricted set of methodologies. As anticipated in the research proposal, our analysis relies on the appropriate definition of a counterfactual to the intervention. In practice, we relied on randomization to construct that counterfactual. This is a significant improvement on the practice of impact evaluation in Lao PDR, which has mostly relied on approaches such as comparisons before-after or with-without program, with well-known limits (see Khandker et al. (2009) for an intuitive critique of those approaches). Section 5.3 describes the general steps followed throughout the analysis.

5.1 Identifying constraints

The diagnostic of the drivers of food insecurity and the characterization of past attempts to reduce its importance followed a variety of methodological approaches, which can be listed as follows:

- As described in section 5.1.1, we constructed an Evidence Gap Map to clearly identify what can be learned from past attempts to reduce food insecurity in the northern region of Lao PDR;
- The identification of past determinants of food insecurity relied on the analysis of secondary data collected by the Lao Statistical Office on consumption and nutritional status (Laos Expenditure and Consumption Survey and Lao Socio Indicators Survey, respectively); the available data was complemented by original analysis of soil properties, as one important component of natural capital that receives a great deal of policy attention; this approach is presented in section 5.1.2;
- Increased agricultural commercialization is a central policy objective of the Government of Lao PDR, raising several questions about their effects, both for consumers and for producers; as presented in section 5.1.3, we relied on an analysis of consumer market integration of several major commodities as well as an analysis of the price effects of different degrees of competition (implemented via bureaucratic regulation) on producer prices; in addition, the project team conducted a value-chain analysis for two major commodities (maize and cattle), in two provinces (Luang Prabang and Xiengkhuang) as described in section 5.1.4;
- Finally, and in tandem with the collection of primary data needed for the value chain analysis, we collected and analysed an array of potential explanations for the discrepancy between poverty reduction and reduction in food

insecurity; methodologically, the statistical analysis of this data is identical to what is described in section 5.1.2 but, given its importance in the definition of some of the pilot interventions, we briefly describe it in section 5.1.5.

5.1.1 What can we learn from past attempts to reduce food insecurity in northern Lao PDR? An Evidence Gap Map

An Evidence Gap Map (EGM) is an approach to systematically summarise and present the evidence on a selected topic, allowing for the identification of where evidence is absent. The approach was developed by researchers at the International Initiative for Impact Evaluation (3ie) and is described in detail in Gaarder (2010) and Snilstveit, Vojtkova et al. (2013). This approach has been used to provide easy access to the "best available evidence" on the outcomes of programs that have targeted, for example, HIV/AIDS in low and middle income countries (Vojtkova 2011), smallholder agricultural development in Africa (Stewart, Erasmus et al. 2014) and, more recently, agricultural innovation (Lopez-Avila et al, 2017) and the effect of food systems interventions on food security and nutrition outcomes (Moore et al, 2021). The application of this approach to our question is described in more detail in Leroux et al (2016). Here, we present its main steps, with the objective of supporting a self-contained interpretation of its conclusions (which we present in section 7.1.1).

Thematic EGMs usually limit admissible evidence to impact evaluations and systematic reviews of impact evaluations. The motivation behind the EGM developed as part of this project was to identify, map and catalogue the considerable effort expended to improve food security in the Northern Uplands of Lao PDR. This is done by admitting a wider range of published evidence on outcomes than is common in EGM studies, including final and mid-term project reports.

In order to minimize the potential for bias in the identification, review and mapping stages, a step by step process was defined *a priori* and followed throughout. Each of these steps is explained in more detail below.

Step 1: Defining the objective, scope and EGM framework: Given our objectives (identify and summarise pertinent interventions and their outcomes for food security in the north of Lao PDR), we limited the scope of the search for evidence to projects that were implemented in the Northern provinces, and were concluded in or sometime after 2005 and were therefore likely to have targeted drivers of food insecurity that were still of relevance for our own project. The food security EGM framework is grounded in the work of the Food Security Learning Framework (Gates Foundation, DfID et al. 2013) and encompasses the four pillars of food security (access, availability, utilization and stability; FAO (2001)). This basic framework was presented and discussed with local stakeholders during the inception project workshop held in Vientiane in November 2015.

The outcome of this step is shown in Figure 1. The rows contain the types of interventions, grouped by target level (enabling environment, households or individuals) while columns cover the six dimensions of food security (improved livelihoods, resilience, markets, nutrition, natural resource management and equality). We explicitly excluded R&D and policy research as the outcomes of such interventions are particularly hard to define, may only become apparent long after the implementation and, as a rule, tended to be national in focus.

The EGM is complemented by a brief synthesis of each project/program, with the structure presented in Figure 2. This description contains information on the details of the project and the source of this information, an overview of the scope and a classification of the activities undertaken and their outcomes. Importantly, it also

contains a brief description of the methodology used to evaluate the project outcomes.

Vertical: target levels of intervention	Horizontal: dimensions and outcomes of food security					
	1. Improved livelihoods	2. Increased resilience	3. Expanded markets and value-chains	4. Enhanced nutrition and dietary quality	5. NRM & CC	6. Equality
Enabling environment	> Agricultural yield / production > Adoption of innovations > Ownership of productive assets	> Coping strategies > Risk reduction > Social capital	> Access to output markets > Access to improved inputs > Production of high value outputs	> Food consumption > Diet Diversity > Feeding, nurturing, mothers' health	> Biodiversity > Forest management > Water management	> Gender > Social
Household	> Production for own consumption > Diversification of income generating	> Human capital	> Effect on prices: level and variability > Quality standards	> Anthropometric gains > Water & health practices	> Erosion	
Individual			> Post-harvest loss	> Health service provision / training / access > Access to clean water		

Figure 1: Food security EGM framework

Step 2: Searching for interventions The scope of the EGM defines the search parameters that were used to identify candidate projects and interventions required to i) target one or several of the food security dimensions described in Figure 1, ii) implemented in one or more of the Northern provinces of Lao PDR and iii) completed sometime after 2005). As described in more detail in Leroux et al (2016), between May and August 2015 we searched for relevant projects and interventions on project and literature data base searches as well as in the grey literature. We also conducted targeted searches of key donor and implementing agencies' websites.

Step 3: Sourcing missing information. This step involved finding and removing duplicates from our compiled database of identified projects and searching for missing information and published project evaluations. A range of different search strategies were used. Again, these are described in detail in Leroux et al (2016). It is important to notice that gaining access to the final reports and impact evaluation studies proved challenging and we were able to source written reports only for about half of in-scope projects identified in step 2. As a result, the findings of this analysis reflect the in-scope projects for which information is available, and no other criterion (that could have biased the patterns revealed in the EGM) played a role.

Project	ID		
	Name of Intervention		
	Implementing Agencies		
	Funding Agencies		
	Budget		
Report	ID		
	Title of Report		
	Publication Date		
	Authors		
	URL if available		
	Contact Person		
Project Overview	Main objective of Intervention		
	Activities		
	Dimension of food security targeted	Livelihoods	☐
		Resilience	☐
		Markets and value chains	☐
		Policies and institutions	☐
		Nutrition and Dietary Quality	☐
		Natural Resource Management and Climate Change	☐
		Equality	☐
	Food security pillar targeted	Availability	☐
		Access	☐
		Utilization	☐
		Stability	☐
	Who was targeted?	Enabling environment	☐
		Households	☐
		Individuals	☐
Scope	Timeframe		
	Region		
	Province (Districts)		
	Number of villages		
	Number of households/individuals		
Methodology	Evaluation methods employed		
	Baseline data collected?		
	Endline data collected?		
	Data collected on which outcomes?		
	Counterfactual identified?		
Key results	Results		
Other Results	Includes: - Qualitative results - Unintended outcomes		
Comments			

Figure 2: Project summary template

Step 4: Critical appraisal and population of EGM. This step involved completing the summary template reproduced as Figure 2, for each project and assessing the methodology used to evaluate the impacts of the project, paying particular attention to the strength of evidence. This ranged from outcomes that were evaluated using a

baseline and counterfactual (stronger evidence) to outcomes that are evaluated using a baseline but no counterfactual (weaker) and evaluations that rely on other types of information and usually do not have access to a baseline (weak). Any mapping process of this sort necessarily involves judgements. To minimize the potential for systematic biases, each study was catalogued and mapped by two researchers independently. The project summary and EGM mapping for each project were then compared. In the case of discrepancies, the reasons for and against specific mapping or cataloguing decisions were discussed until a consensus was reached.

Step 5: Interpreting results and drawing conclusions The EGM is designed to provide two types of insights. Firstly, what type of interventions are being implemented and which dimensions of food security are being targeted? Combined with information about the methodology used to evaluate the impact of the project allows us to conclude the degree to which strong conclusions about successes and failures of interventions can be drawn. Secondly, the gaps in the EGM reveal the dimensions of food security that have not been subject to an intervention.

5.1.2 Quantifying the determinants of food insecurity: 2007-2012

Socio-economic constraints

The identification of socio-economic drivers of food insecurity relied on data from the Laos Expenditure and Consumption Surveys (LECS), in particular LECS4 (2006/07) and LECS5 (2011/12). The data collected as part of LECS allows for a characterization of the livelihood choices of households, as it covers aspects such as migration, non-farm jobs and businesses, as well as different aspects of agricultural production and commercialisation. In addition, this survey includes detailed data on consumption of different foods, using a diary collected over the period of one month. Data on consumption can then be used in conjunction with data on nutrient availability, from standard Food Composition Tables, to determine whether minimum nutritional standards are met. Finally, the impact of policy variables such as access to roads or to regular markets can be quantified using data collected as part of the village questionnaire collected as part of LECS.

Despite its high quality, LECS suffers from one important limitation for our analysis: it does not collect data on anthropometric measures, a reliable way to measure the importance of malnutrition, particularly among children younger than 60 months. We overcome this limitation through the analysis of data collected through the Lao Socio Indicator Survey (LSIS) in 2012. This survey (that follows the structure of the Demographic and Health Surveys – DHS) includes detailed anthropometric information but is, however, much more limited in terms of food consumption.

Biophysical (soil) constraints

The socio-economic data was linked with data on soil properties. The focus on soil properties reflects two considerations: firstly, the relatively low use of external inputs (particularly fertiliser) that characterises Lao agriculture and, consequently, the relative importance of soil capacity as a constraint to agricultural production; secondly, the policy focus on land degradation, as evidenced by the continuing debate about shifting cultivation.

Linking the two types of data relied on soil property maps, predicted using existing soil samples. We used the data made available by the Soil Survey and Land Classification Centre (SSLCC), derived from the description and soil analysis of 3471 soil pits (Chaplot, Bounthong and Valentin, 2010). The data available has information on the following properties: clay content, bulk density, soil organic carbon (SOC),

available phosphorus (avail-P), available potassium (avail-K), nitrogen (N), cation exchange capacity (CEC), base saturation (BS%) and pH. This data provides the basis for the existing soil classification, according to the FAO/UNESCO WRB soil classification system. The spatial structure of these soil properties was combined with fine-detailed environmental variables such as topographic information (elevation, slope, curvatures, etc.) derived from a 50 m digital elevation model (DEM), climate variables, and land use/vegetation information derived from remote sensing images.

The link between the different types of information allowed for the characterization of the spatial distribution of these properties at a detailed resolution (pixel size 100 m x 100 m) using the recently-developed digital soil mapping techniques discussed in Minasny et al (2013). The resulting maps of soil properties were used to predict soil functions such as crop production, water holding capacity, etc., and land degradation such as soil erosion potential or soil fertility status.

The conversion of land quality attributes (e.g. nutrient and moisture availability) affecting individual land use types (e.g. rice, maize, coffee) from the primary land attributes (e.g. avail-P, soil pH, SOC) enabled the production of land capability maps. This step involves the identification of suitable critical limits for each primary land attribute that affect each land use type and the development of a decision tree to translate the geo-referenced soil units into potential land-use types. Characterising the soil to function for a particular land use enables an evaluation of land suitability, and if the land can be described as degraded by relating this back to the soil stocks described earlier.

Identification of the hierarchy of drivers of food security

Using the data described above, we can identify the drivers of change in food security status through the estimation of the following model:

$$(1) \qquad FS_{ihlt} = \alpha_i + \beta_1 X_{iht} + \beta_2 Y_{ht} + \beta_3 Z_{lt} + \varepsilon_{ihlt}$$

where FS_{ihlt} is an indicator of food security (for example, calorie consumption) of person *i* in household *h* and location *l* at time *t* and the βs are our coefficients of interest, measuring the effect of individual (X), household (Y) and location (Z) variables that may matter.

It is simple to adapt this analytical framework to the analysis of nutrition at individual level (as measured by anthropometric indicators, for example). Essentially, the indicator of food security would be replaced with anthropometric indicators (height-for-age z-score of children under 60 months, for example) and the range of explanatory variables would need to be expanded to include individual characteristics (such as gender and age of the individual, for example, but also access to water and sanitation, health care, and other variables that influence nutritional status beyond food consumption).

In this approach, the estimates associated with each variable can be interpreted as causal (hence, the use of the term “driver”) under the relatively strong assumption that there are no omitted confounders of the food security status. The availability of multiple observations for the same individual, collected using a similar questionnaire, in LECS allows us to use panel data techniques to overcome the limitations of cross-sectional analysis and obtain consistent estimates of the parameters of interest.

Estimates of equation (1) can provide an interpretation of the relative importance of the drivers (or, at least, the predictors) of food insecurity under the assumption that, conditional on the set of measured confounders of food security, all observations belong in the same model – that is, that there is no fundamental heterogeneity in the relation between each variable and the outcome of interest. The policy debate about

food security in northern Lao PDR is, however, shaped by the perception that heterogeneity is essential to understand living standards (a perception that motivated the initial characterisation of the focus of this project to the “uplands”).

One way to approach this concern is to rewrite equation (1) as

$$(2) \qquad FS_{ihlt} = \begin{cases} f_1(X,\ Y,\ Z) \text{ if } W_1 \leq w_0 \\ f_2(X,\ Y,\ Z) \text{ if } W_1 > w_0 \end{cases}$$

where depending on whether a specific variable W_1 is above or below a certain cut-off (w_0) leads the effect of other variables (X, Y, Z) to be better expressed by function f_1 or f_2, respectively, rather than a common function (as in equation (1)). The selection of variables W_1 and associated threshold levels, w_0, leads to the identification of a hierarchy of importance in determining food security status (Loh, 2002). If the variable W_1 can be manipulated through policy, has the causal impact we attribute to it and one of the identified food security status (for example, the one associated with f_2) is associated with higher levels of welfare, then the results of the analysis also suggest where most of the policy effort should be put – in moving communities or households to levels of W_1 that are above w_0.

In practice, the identification of the different variables W_1 (and associated thresholds, w_0) can be done through the use of regression trees, a machine learning technique that allows for the identification of patterns in the data relating food insecurity with its drivers and the hierarchy of importance of different constraints and, in particular, the possibility of thresholds in this relation (Yohannes and Hoddinott, 1999).

Although this approach was adopted in this context, it delivered a surprising “non-result”: conditional on the wide set of possible confounders, no variable emerged as a potential split variable that would divide well defined sets of households into different sets of relations between food security and the explanatory variables. The conclusion then is that no essential heterogeneity can be detected in the data or, in other words, that the relation between household characteristics and outcomes is essentially the same in this region. For this reason, we did not target any of the pilot interventions to well identified sub-groups defined by ethnicity, location or access to infrastructure.

5.1.3 Characterizing market integration of major agricultural products

Market integration concerns the flow of goods and information, and thus prices, over space, form and time, and can be defined as tradability between markets. Barrett (2008) defines tradability as the fact that a good is traded between two economies or that market intermediaries are indifferent between exporting from one location to another or not doing so. The concept of market integration is closely related to concepts of efficiency, since analysis of spatial market integration provides an indication of competitiveness, effective arbitrage, and efficient pricing (Sexton, Kling and Carman 1991). For these reasons, integration of markets is often considered a precondition for their effective reform (Baulch 1997).

In the analysis conducted as part of this project, discussed in more detail in Nolan (2016), the main focus is on spatial market integration, which may be evaluated in terms of a relationship between prices of a commodity in spatially separated markets, where prices move together and price signals and information are transmitted smoothly. Two regions are in the same economic market for a homogeneous good if the prices for that good differ by exactly the interregional transfer cost (Sexton, Kling and Carman 1991). If linkages exist, price shocks in individual markets should evoke responses in others, a relation that can be quantified through the analysis of temporal variability of market prices. Regions may not be linked because of an

absence of arbitrage (autarkic markets); or because of impediments such as poor access, trade barriers, imperfect information or risk aversion; or because of imperfect competition in one or more markets.

This analysis of market integration had two aims. Firstly, to determine the extent to which provincial markets are integrated, and secondly, to investigate which provincial characteristics are important in explaining the extent of market integration. See the work of Ismet, Barkley, and Llewelyn (1998), who use weekly provincial level data on retail rice prices for Java and off-Java rice prices during the period 1982-1993, and Varela, Aldaz-Carroll and Iacovone (2012; 2013) who measure spatial integration among Indonesian provinces in the markets for rice, soybeans, maize, sugar and cooking oil using monthly price time series, for methodologically similar work.

Given data restrictions, we were limited to the analysis of price data over time, (as data on quantities traded does not exist), for all main consumer markets at the level of province capital, for up to 48 months from January 2011 to December 2014 for seven food items (paddy sticky rice, paddy steam rice, and first quality Lao sticky rice, Lao steam rice, beef, buffalo, and pork).

We tested for a common stochastic long run trend by performing Johansen-Juselius cointegration rank tests (Johansen 1988; Johansen and Juselius 1990) on all pairs of provincial prices for the commodities under consideration. This test suggests cointegration when the trace statistic (Johansen's co-integration test statistic) is higher than a critical value. The two series are then said to share a common stochastic long-run trend. The higher the trace statistic for a pair of provincial prices, the more strongly co-integrated the series. Tests of stationarity in the distribution of pairs of markets (prices) rely on comparison of the trace statistic with the appropriate Osterwald-Lenum (Osterwald-Lenum 1992) critical value, which depends on the assumptions regarding the presence of intercept (assumed to exist in our analysis) or trend (assumed inexistent) terms.

Once we have the measure of the strength of cointegration, we are interested in determining the factors which influence the extent of market integration. We use the trace statistics for pairs of provincial capitals (generated in the first step, above), and regress the trace statistic on a number of provincial variables. Because there are two provinces in each pair we include the characteristics of both provinces in the regression. We then estimate the joint effect of the province characteristic on the dependent variable (trace statistic, as proxy for strength of cointegration). The empirical model takes the form:

$$(3) \qquad Ln(TS_{ij}) = \beta_0 + \beta_1 X_i + \beta_2 X_j + e_{ij}$$

where $TSij$ is the trace statistic between markets i and j and X is the set of variables used to explain cointegration between pairs of markets, and is similar those used in previous studies, subject to data availability: transaction costs, market infrastructure, technology adoption, population and production per capita. In addition to OLS, we also estimate this model using a Seemingly Unrelated Regression model for the different forms of rice to determine whether the four included rice markets are correlated.

5.1.4 Value-chain analysis of maize and cattle, and the importance of market regulation

Value chain analysis

Given the importance of commercialisation in the agricultural strategy of the government of Lao PDR, and the gaps in knowledge regarding the impact of these changes on local livelihoods and food security, we analysed the structure and

performance of the value chain of two of the main commodities, maize (which has since the start of the project lost some importance in terms of production and exports) and cattle (which gained an extraordinary importance during the same period). These choices were guided by a decision to avoid “niche” commodities, that are likely very important in some local contexts, but are difficult to be widely adopted across a variety of production conditions and, as such, would have limited ability to explain future trends of development in the region.

The analysis required the collection of primary data and, for that reason, was limited to two provinces. Following discussions with the Government of Lao PDR (at both central and provincial level), Luang Prabang and Xieng Khuang were identified as target provinces, given that they were characterized by both relatively high rates of food insecurity and high rates of vulnerability to food insecurity due to price shocks (WFP, 2007).

The approach involved an analysis of the agribusiness systems including constraints in the enabling environment, the definition of the elements of the agribusiness systems analysis of involvement of smallholders in these chains as well as the opportunities and constraints to their involvement (see Murray-Prior, Batt, Hualda, Conception, Rola-Rubzen (2014) for an example of the adopted approach). This analysis adopted well established tools of value chain analysis (Vermeulen, Woodhill, Proctor, Delnove (2008), M4P (2008)) including: mapping the chains; mapping key policies and institutions that influence the functioning of the chains (including governance, coordination, regulation and control) and establishing key drivers, trends and issues affecting the chain and its actors (including relationships in the chains, social, human and built economic capital and costs, margins and income distribution along the chains).

This analysis was complemented by a qualitative evaluation of the effects of increased market integration in a few selected villages. The objective of this research was to gain detailed evidence on their operation, including an analysis of who benefited (and why), which were expected to be difficult to answer reliably with quantitative economic surveys.

The study was designed to combine information on social structure with semi-structured interviews with village key informants and householders, and some participant observation (albeit in a highly compressed format due to time constraints on the field team members). The interview questions concentrated on the relationships between recent increased engagement with agricultural commodity markets (particularly corn), inequality, and traditional cultural institutions of reciprocity and social security. A key assumption was that if increased market engagement would have eroded social ties by making people more individualistic in orientation and by increasing inequality, then food security might be affected negatively through the weakening of traditional social support systems.

The study was conducted in four villages (two in Pakxeng, and two in Kham), selected with the assistance of the local DAFO. Four students and one supervisor from the Faculty of Social Sciences at NUOL based themselves in each of two districts and visited two villages in succession. The time each team spent in each village was limited to 5-6 days. Each team aimed to speak to representatives of 20 families in each village, spanning the full spectrum of wealth, from richest to poorest. The team did not have time or resources to look closely at diet or to obtain any detailed empirical measure of food security per se, and focused instead on how engagement with new markets (mostly, for corn) drove inequality in assets (land) and on the potential effects of these changes in social insurance.

The importance of market regulation: market structure and welfare outcomes

In addition to data on the enabling environment, collected as part of the village and household surveys fielded to characterise the value-chains of these two commodities, two researchers in the team (Paulo Santos and Silinthone Sacklokham) conducted a series of semi-structured interviews with bureaucrats responsible for the provincial and district offices of the Ministry of Agriculture and Forestry and the Ministry of Commerce. These interviews were conducted in February 2017, with the objective of understanding the stated reasons for different modes of market regulation, which ranged from free entry of traders (subject to the payment of a relatively small fee) to the formation of monopsonies, typically allocated to the trader who paid the highest amount to the district authority.

These interviews supported several conclusions, which are presented here because they had implications for further work conducted as part of the project. These are:

1) The fundamental determinant of a choice of market structure is the trade-off between expected budget revenue, the risk of not meeting revenue raising targets defined by Province and District governors and the costs of raising this revenue;

2) With these trade-offs in mind, there was ample experimentation across commodities and through time, with local officials moving between different systems according to whether it "worked" (ie, it raised enough revenue to meet budgetary targets) in the previous iteration;

3) There was a universal recognition that limiting competition hurt producers, who received lower prices than they otherwise would, and that regulation decisions potentially created incentives for illegal trade between provinces, with additional transaction costs for both producers (who tried to evade them) and bureaucrats (who were in charge of implementing them).

The last conclusion led to the abandonment of one activity included in the original project proposal (use experimental games to test knowledge about the effects of increased competition on society's welfare, given that local bureaucrats were clearly aware of those consequences) and raised the need to quantify, as best as possible, the potential costs to producers due to limited competition in selected commodities.[1] This was done through a survey, fielded to all DAFO in the northern provinces (and not just in Luang Prabang and Xieng Khuang) through which we collected data on market structure and prices of three commodities (rice, large ruminants, maize). The results of the analysis of this survey are presented in section 7.6.

5.1.5 Beyond income: additional explanations for the persistence of food insecurity

The analysis of existing regulations, of the structure of the value chain and of the extent of market integration forms the background to any policy recommendation regarding the role of markets in promoting agricultural development and food security. The main mechanism through which such changes will impact on household welfare (including food security) are income (and its vulnerability to market shocks). However, the historical experience of Lao PDR suggests that there is a decoupling

[1] In the proposal, we suggested that "(…) it seems important (and practically feasible) to understand the potential impacts of any suggestion of deregulation/ increased competition, given that alternative market structures have been observed to lead to very different outcomes when there are changes in policies. We propose to use economic experiments in the field to guide policy development, through an investigation of price discovery, market efficiency and welfare impacts of deregulation and increased competition." This activity was abandoned as a result of the fieldwork activities described.

between increases in income and improvements in food security. Although our analysis of microeconomic data suggested that such conclusion (based on rough estimates of correlations between macroeconomic aggregates of poverty and food insecurity rates) needs to be moderated, it seemed important to explore what additional explanations may drive such lack of relation. The focus of the analysis was then directed to how households decide on how to spend available income.

This led to a set of hypotheses, that were explored using the same primary data that was collected to analyse the structure and performance of the maize and cattle value chains. This data was collected among 10 randomly chosen households, in 16 villages in the districts of Viengkham and Pagxkeng (in the province of Luang Prabang) and an equal number of households and villages in the districts of Phoukhout and Kham (in the province of Xiengkhuang). Succinctly, we explored the following hypotheses:

- In the absence of insurance, shocks to production, including the importance of post-harvest losses, may attenuate the link between increases in income and improvements in food security given the need to self-insure (covariate shocks) or the reduction in income that is not detected in macroeconomic aggregates (idiosyncratic shocks);
- Households engage in mental accounting, the practice of reserving specific income (by source) to specific uses, which may not include increased spending on food (but be directed to other spending, like education, housing, etc, that are perceived as more important than improved diet);
- There are frictions within the household regarding how to spend additional income, reflecting differences in preferences: if, for example, the household member who makes decisions regarding consumption has limited power to benefit from increases in income (because it is being earned and/or managed by a different household member, with different preferences regarding how to spend such income), then such intra-household differences in preferences and power may drive the lack of relation between increases in income and improved diet;
- Finally, it is possible that managing a limited number of sources of income with marked seasonality (the main harvest, seasonal labour outside the farm, the selling of livestock) over an extended period of time, and in the absence of accessible saving mechanisms, creates ample opportunities for impulsive spending, which may then lead to increased periods of food insecurity. Although such lack of self-control is likely to be a universal characteristic, it is likely that its consequences are particularly negative for those households that are most vulnerable to food insecurity.

5.1.6 Identifying constraints: a summary

The first phase of this project focused on providing answers to the first research question, by clarifying what can be said about the drivers of food insecurity in the northern uplands of Lao PDR. A significant part of the analysis relied on secondary data, particularly household expenditure and consumption data (collected through LECS), but also nutritional data (collected via LSIS).

Given the dynamism of the agricultural transformation in the north of the country, and the importance given to commercialisation as the driver of that process, we complemented this analysis with the collection and analysis of primary data, focusing on market functioning of two commodities (maize and cattle) in a limited number of areas where vulnerability to market shocks had been identified as greater (four districts in the provinces of Luang Prabang and Xiengkhuang). The focus then was

on a prospective analysis of what may constrain households from participating in the ongoing agricultural transformation in the area, and how that may affect their food security status.

There are important methodological differences accompanying the differences in data and geographical scope. While the analysis of past drivers of food insecurity relied exclusively on the econometric analysis of representative datasets, the analysis of primary data was methodologically more diverse, and allowed for a wider set of explanations, although naturally in a more restricted set of geographical circumstances. We approached the two types of analysis as complementary of each other, both contributing to a choice of feasible ways to improve the food security status of impacted populations.

5.2 Selection of interventions

The selection and definition of pilot interventions aimed at improving household food security consisted in the ranking and selection of potential interventions, through a process of stakeholder consultation (a public workshop held in Vientiane in May 2017), followed by an in-depth discussion with the members of the Steering Committee. This stage of the project addresses the question “To what extent is the intervention expected to be able to improve food security among vulnerable populations?” along two dimensions: *ex ante* (theoretical) impact and feasibility. Selected interventions should address a high need, be expected to deliver a high benefit/cost ratio, in a relatively short time and be potentially sustainable while not having been rigorously evaluated in the context of Lao PDR. Figure 3 represents this decision process.

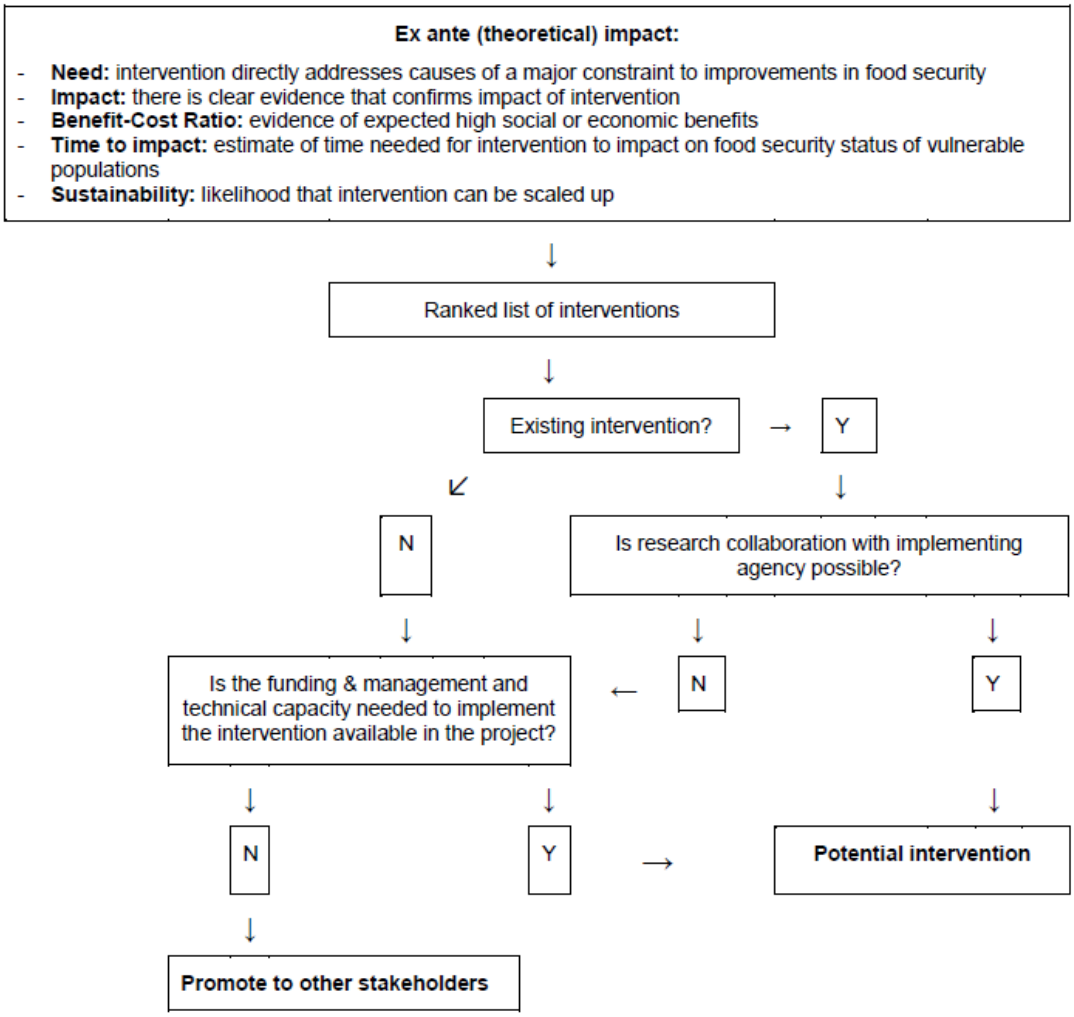


Figure 3 – Selection of pilot interventions: decision process

5.3 Experimentally evaluating the impact of selected interventions

We used field experiments/randomised control trials (RCTs) to define the counterfactual of each of the three interventions defined in the previous section. Under appropriate assumptions, that are known and amply discussed in the literature, experiments provide a relatively straightforward way of obtaining consistent estimates of the average effect of a program. In addition, and as we had the possibility of observing in the field, when discussing the implementation of all pilots, the intuition behind the definition of an experimental control group is fairly easy to explain to agencies that, ultimately, will make use of the research results.

This section presents the following information:

- statistical basis of the experimental design (power calculations) - section 5.3.1
- addressing the integrity of the experimental design – section 5.3.2
- estimating Average Treatment Effects(ATE) – section 5.3.3
- quantifying heterogeneity in ATE – section 5.3.4

- quantifying mechanisms – section 5.3.5
- quantifying spillover effects – section 5.3.6
- quantifying willingness to pay – section 5.3.7

Gerber and Green (2012) provides guidance on all of these aspects (with the exception of those discussed in 5.3.7), and we provide further references that guided our decisions where appropriate. In addition to quantitative approaches, we relied on two qualitative evaluations of these interventions, which are discussed in section 5.3.8. Socioeconomic data collected as part of this project is summarised in Appendix 1.

5.3.1 Power calculations

Providing credible estimates of the impact of pilot interventions requires the definition of adequate sample sizes. The statistical basis of this calculation are well known, but their application always relies on choices. For clarity these are presented here:

- Hypothesis: we define “the pilot intervention has no effect on the outcome” as the null hypothesis, with a two-sided alternative hypothesis;
- level of the test (ie, acceptable level of Type I error): 0.05, as standard
- power of the test (ie, probability that we will be able to detect an effect if indeed there is one, identical to 1-probability of Type II error): 0.80, as standard;
- minimum detectable effect of the intervention (ie, minimal change in outcome that makes the intervention worthwhile – or, in other words, minimal change below which the null hypothesis of no effect may as well be accepted) expressed in terms of SD of outcome;
- intra-cluster (village) correlation of outcomes: 0.10, as measured in existing data;
- share of clusters allocated to treatment: 50%

The determination of number of households interviewed in each village (cluster) was made considering the number of enumerators per team (four) and the expected duration of interviews in each wave (up to 90 minutes per household), which suggested, based on previous experience, that 3 households per enumerator per day (hence, 12 households per village) would be ideal. With this information, we used the freely available software Optimal Design (Raudenbush et al (2011)) to determine the number of clusters included in each study. The results and the underlying information are summarised in Table 1.

Table 1 – Assumptions underlying power calculations

	Rodent control	Demand led extension
Level of test	0.05	0.05
Power of test (minimum)	0.80	0.80
Main outcome of interest	Losses due to rodents	Food security
Standardised minimum detectable effect	0.20	0.35
Intra-cluster correlation	0.10	0.10
Number of households per cluster	12	12
Total number of clusters	36	72

Villages were selected randomly from the list of villages surveyed as part of the Agricultural Census 2011/12. The rodent control intervention was only piloted in Luang Prabang, as the problem was not considered important in Xiengkhuang (despite average losses post-harvest of approximately 10%). Villages that were surveyed during the diagnostic stage of this project were allocated to treatment status in the Demand Led Extension pilot.

It should be noticed in advance that *ex-ante* power calculations are particularly difficult in the case of projects such as the intervention on Demand Led Extension that we piloted, given that the variety of public goods (in this case, the topic of the training) potentially demanded by beneficiaries is quite large. As a result, the number of beneficiaries of each topic is reduced, with consequent reductions in the power to detect differences between treated and control individuals. As we will see (section 7.4), our study suffers from that shortcoming in some outcomes, although the concentration of initial choices of training topics on livestock management allowed us to provide credible estimates of more detailed impacts.

5.3.2 Addressing the integrity of the experimental design

Randomisation allows the identification of consistent estimates of the effect of a treatment under several conditions:

- Absence of additional confounding effects;
- Absence of randomization bias;
- Stable Unit Treatment Value Assumption (ie, no spillovers).

We address these concerns in the following way:

Absence of additional confounding effects. We test whether the distribution of potential confounders (ie, variables that potentially determine the outcome) is statistically undistinguishable between treatment and control groups by presenting *t*-tests of the hypothesis that H0: E(X | T=1) = E(X | T=0).

As it is known, when considering a large number of potential confounders, it is expected that this null hypothesis will be rejected in some (few) cases. To address concerns about overall importance of this lack of balance, we also present *F*-tests of overall significance of the set of confounders (X) as explanatory variables of treatment status.

Absence of randomization bias. We consider two main problems: selective attrition and non-compliance with treatment status. We estimate the importance of selective attrition (ie, differences in re-surveying rates that are correlated with treatment status) by estimating the following regression using OLS:

$$(4) \qquad Attrition_i = \alpha + \beta T_i + \varepsilon$$

where Attrition is a indicator variable that is equal to 1 if the unit is interviewed at baseline but not at follow-up survey and T_i indicates treatment status. Selective attrition is presumed if β is statistically different from 0. When that is the case, we will use the approach suggested in Lee (2009) to estimate bounds to treatment effects that are subject to minimal assumptions about the attrition process.

Non-compliance (units in treated clusters that do not take part in treatment: for example, households in villages where the rodent control contest is organised that do not participate in it) is the second cause of randomization bias. Its importance either invalidates or complicates the identification of treatment effects, given that it re-introduces selection into the estimation of treatment effects. We address this potential bias by presenting either Intention-to-treat estimates or Instrumental variables/ Local Average Treatment Effects (see next sub-section).

Finally, we address the possibility of spillovers between treated and control units mostly via data collection, as we will collect data on outcomes and confounders for households, in treatment villages, that choose to participate in the different interventions and those that don't. Given the data on household characteristics, including lagged outcomes, a comparison with observationally similar households in control villages, using propensity score matching, would then allow us to estimate any change in outcomes for households that did not participate in the piloted interventions but that were indirectly impacted by it. See Angelucci and De Giorgi (2016) for a similar analysis.

5.3.3 Estimating Average Treatment Effects (ATE)

In the absence of concerns about attrition or covariate imbalance, randomization of treatment status allows us to estimate the average effect of this intervention on an outcome of interest (Y) through the expression:

(5) Average Treatment Effect (ATE) = E(Y|T=1) –E(Y| T=0)

where the two expressions on the right hand side of the equation are expected values of the Y conditional on benefiting from the project (T=1) or not (T=0). More generally, the ATE can be estimated using Ordinary Least Squares (OLS) to estimate the equation

(6) $Y_1 = \alpha + \Theta Y_0 + \beta T_1 + \gamma X_0 + \varepsilon$

where the subscripts 0 and 1 indicate that values were measured before or after treatment, Y and T have the same meaning as above and X is the set on unbalanced covariates at baseline. Standard errors are clustered at village level, and when dealing with a small number of clusters, we also present wild-bootstrap clustered standard errors (Cameron et al. (2008)). Finally, where appropriate, we correct for False Discovery Rate (PDR) when testing for multiple correlated outcomes using the approach described in Benjamini et al (2006).

The ANOVA approach identified in the previous equation increases the power to detect an effect when outcomes are not highly correlated across periods (McKenzie, 2012). When that is not the case, a Difference-in-Difference approach is potentially preferable. In those cases we use OLS to estimate the following equation

(7) $Y = \alpha + \beta_1 T + \beta_2 t + \beta_3 (T \times t) + \varepsilon$

where t stands for time period (0 at baseline, 1 at follow –up) and we are now particularly interested in the estimate of the interaction between treatment and time (ie, β_3).

Finally, in terms of estimators, we primarily focus on Intention-to-Treat (ITT) estimates, which measure the average effect of offering a program (for example, the ITT estimate of the impact of the rodent control contest on rice losses measures the effect of such contest in terms of average losses by a household in a treated village due to the fact that the contest was organised in a village, even if no member of a specific household participates in the contest). The advantage of this estimator is that it only relies on the randomization of treatment status to be identified.

In some cases, we are however interested in the effects of the program on those who participate. Given that participation is always voluntary, this focus brings back selection bias to the analysis. As it is standard in this type of analysis (Imbens and Angrist (1994)), we then estimate Local Average Treatment Effects (LATE), which rely on Instrumental Variables (IV) estimates of the effect of the program, with randomization used as an IV.

5.3.4 Quantifying heterogeneity in ATE

In most cases, we will be interested in sub-group analysis of ATE to understand whether the effect of a program is moderated by beneficiaries pre-treatment characteristics (eg, age, gender, initial wealth). We estimate those sub-group effects by using OLS to estimate the following equation:

$$(8) \qquad Y_1 = \alpha + \Theta Y_0 + \beta T_1 + \gamma X' + \Psi (T1 \times X') + \varepsilon$$

where X' is the set of moderators in which we are interested and we are now particularly interested in the values of the interaction between treatment status and moderator (ie, Ψ). As it is known, these sub-group effects do not have a causal interpretation, given that randomisation was not performed at the level of the sub-group but, nevertheless, they may indicate any differential impact of the program under evaluation.

5.3.5 Quantifying mechanisms

To quantify the importance of the different causal pathways of the treatment effects, we use a causal mediation analysis suggested by Imai et al. (2011). This approach uses a mediation variable to disaggregate the effect in a mediator or indirect effect (the average causal mediation effect, ACME) and a direct effect.

In a first step of this approach, a mediation as well as an outcome model is estimated. The specifications of the models are the following:

Mediation model:

$$(9) \qquad M_i = \alpha_m + \beta_m T_i + X_m \delta_m + \varepsilon_{m,i}$$

Outcome model:

$$(10) \qquad Y_{i,t=1} = \alpha_o + \mu_o m_i + \beta_o T_i + X_i \delta_o + \varepsilon_o$$

where m_i and X_i are the mediation variable and all pretreatment variables that are of relevance, respectively,

In a second step, predictions of the mediation variable are calculated separately for treated and non-treated observations and used to predict the outcome model under the treatment. ACME is the difference of both predictions of the outcome model. Confidence intervals are then obtained using the delta method and Monte Carlo simulations.

As made clear by Imai et al. (2010a), the identification of this relation as causal relies on the validity of the sequential ignorability assumption, which is a sequence of two ignorability assumptions. The first part is an exogeneity assumption, which implies that both outcome and mediator variables are, conditional on all observed pretreatment covariates, statistically independent (ignorable) of the treatment status. Because of the randomization in our experiment, we can expect that this part of the assumption holds. The second ignorability assumption says that the mediation variables are independent of the outcome variables conditional on treatment and all covariates of importance. In other words, the results of the outcome models would be biased if there exists an unobserved confounder which affects both the mediation and outcome variables.

As with any other test of exclusion restrictions assumptions, a test of the sequential ignorability assumption is not feasible. For that reason, we are limited to do a sensitivity analysis for to test the robustness of our estimates to potential violations of this assumption (see Imai et al., 2010a; and Imai et al., 2010b). To be more specific, we can test how much the sequential ignorability assumption must be violated for the sign of the ACME estimates to change. An unexplained confounder would influence

the mediation and outcome model, which would be detectable in a correlation of the error terms.

Using simulations with 1000 repetitions, we can estimate the maximum disturbance of the unobserved confounder for the assumptions to be violated. First, we estimate the size of a correlation between unobserved confounding variable and outcome and mediation variable which would be necessary for the ACME estimates to become zero. Second, we test how much of the variation is necessary to be explained by a confounding pre-treatment variable that one of the estimated ACMEs becomes zero.

5.3.6 Quantifying spillover effects

It is possible that non-participants benefit indirectly from any program: farmers who do not participate in any training may still learn from neighbours (social learning) and, in the case of rodent control, the production of externalities (lower pest pressure) is an intended outcome of this intervention. Disregarding spillovers may change the CBA (because it disregards indirect impacts) and prevents us from learning about how programs achieve an outcome.

Following Angelucci and di Maro (2016), we estimate both ATE on “eligibles” (ie, participants), and ineligibles (ie, non-participants), which we denote as ATE-E and ATE-I respectively. Given that participation in each of the piloted interventions is voluntary, we rely on matching participants and non-participants in treated with observationally equivalent individuals /households in control villages – ie, units in control villages that would have an identical probability of participating in the program had it been offered. More formally, we estimate:

$$(11) \quad ATE - E = E(Y \mid T=1, D=1, P(X)) - E(Y \mid T=0, P(X))$$

$$(12) \quad ATE - I = E(Y \mid T=1, D=0, P(X)) - E(Y \mid T=0, P(X))$$

where T={1,0} indicates whether a village was randomly allocated to treatment or control status respectively, D={1,0} indicates whether a household non-randomly decides to participate in the program or not, and P(X) is the estimate of the propensity score (ie, the probability of participating in the program given an individual’s characteristics).

5.3.7 Quantifying willingness to pay

An important consideration in discussing the potential scalability of any of the pilot interventions is its financial sustainability in the absence of continued outside funding. We address this concern through the use of stated choice methods (contingent valuation).

In this approach, the program is described to respondents who are then asked about their willingness to contribute to voluntarily funding the described program. The limitations of this approach are well known, but they should at the very least provide some information about whether respondents value the program at all.

Following suggestions from public officials and NGO staff, in one case (rodent control) we elicit WTP in different numeraires – money and rice. The suggestion was that eliciting WTP in rice would increase the total value of contributions, by reducing the importance of cash constraints.

5.3.8 Qualitative evaluation

An ethnographic study of the changes associated with the interventions piloted by the project was initially planned. It was expected that those ethnographies would be particularly valuable in examining inter-household power relations (and how they may

change) as well as intra-household relations of importance to food security (including gender roles and the process of food allocation within the household).

Changes in the composition of the research team in mid-2018 led to the abandonment of this type of work. Instead, the research team collaborated with the Faculty of Social Sciences at the National University of Laos to conduct two shorter qualitative evaluations of the pilot interventions (promotion of contests to reduce pest pressure and the demand led extension). Both evaluations relied, for the most part, on focus group discussions to form their conclusions about the short-term impacts of the pilot interventions.

5.4 Reducing the importance of basis risk in the design of index insurance

In the absence of formal insurance, agricultural households in developing countries adopt a variety of strategies to reduce consumption variability, in the face of large variation in income (Morduch, 1995). The limitations of these strategies are known: they cannot insure against covariate shocks, even when effective to smooth consumption against idiosyncratic shocks (Townsend, 1994), and they may come at a large cost, that may itself perpetuate poverty (for example, by discouraging households from investing in technologies that are, on average, more profitable but also riskier, as argued in Rosenzweig and Binswanger (1993) or Dercon and Christiaensen (2011).

The preferred theoretical solution is to develop multiperil insurance. The practical shortcomings of this solution are also well known (Hazell, 1992): high transaction costs, including audit costs to judge the validity of any claims, compound informational asymmetries making such programs generally unfeasible.

The promise of index insurance is to overcome such limitations by structuring insurance payments as a function of an index correlated with losses rather than losses themselves. Ideally, such index should be easy and inexpensive to objectively measure (in order to reduce transaction costs), unable to be manipulated by either insurer or insuree (so as to eliminate informational asymmetries) and highly correlated with actual losses (so that it can provide effective insurance). Since the early 2000s a large number of pilot studies have attempted to determine first the feasibility of this approach, largely relying on weather indexes, and then their uptake and impact. Several recent reviews (for example, Carter et al. (2017) and Cole and Xiong (2017)) converge on two conclusions: insurance can unlock investment and promote growth but its effectiveness as a poverty reduction strategy is severely diminished by the low demand for insurance by potential beneficiaries.

To understand the puzzle of low demand, it is important to start from recognizing that index insurance is, by design, a second-best approach to insurance (Carter et al., 2017), and that is as useful as the quality of the index used to predict losses (Yuzva et al., 2018). The imperfect correlation between index and losses implies that there will be states of the world that should correspond to payments (because insured losses occurred) but in which payments will not occur (because losses were not predicted). Empirically, the importance of basis risk as an explanation for lower demand has been shown by Mobarak and Rosenzweig (2013), who experimentally estimate the positive effect of locating weather stations (on which contracts will be based) at village level on demand for index insurance in India. Similarly, using longitudinal data for index based livestock insurance, Jensen et al. (2018) found that basis risk is negatively related to insurance uptake.

Despite its importance in the context of northern Lao PDR, it was also clear that the requirements to develop a feasible insurance product that could be piloted and

evaluated (in particular, the need to find a reinsurance company willing to invest in this insurance product) would not be met, given time and financial constraints. Instead, the research team focused its attention on ways to reduce basis risk in the presence of substantial heterogeneity of production conditions, which themselves reflect substantive heterogeneity in biophysical conditions in the northern uplands of Lao PDR. With that objective, we asked three questions, in order:

- How important is landscape heterogeneity in determining rice yield? If the answer to this question is positive, we would expect that biophysical conditions (in particular, altitude and slope) would shape production conditions and, ultimately, the correlation between the index and yield, potentially reducing basis risk. We answer this question by using cluster analysis to form groups of observations that are more homogeneous in terms of yield within-cluster than between-clusters.
- What is the best statistical relation between index and yield? The answer to this question depends on the index used. We build on recent literature that moves beyond weather-based index (reliant on a relatively sparse network of meteorological stations) and explore the possibility of using localized time and site-specific satellite data on Normalized Difference Vegetation Index (NDVI) to predict output, in a way that is inexpensive and timely, while eliminating information asymmetries, overcoming problems of limited data availability inherent to other indexes [references].

  The strength of this relation between index and yield was evaluated using a variety of statistical models, with the best one selected on the basis of the Root Squared Mean Error (RSME) of prediction within the testing sample.

  Based on the best predictive model, it is possible to define actuarially fair contracts for different levels of coverage of yield loss. Contrasting predicted losses with real (past) losses, it is also possible to define the value of observed but not predicted (and not paid) losses, ie, the level of basis risk associated with the contract.
- Can accounting for landscape heterogeneity improve the feasibility of index insurance? We can answer this question through a comparison of the value of premiums and the importance of basis risk for the contracts defined for each landscape cluster and for the whole sample.

6 Achievements against activities and outputs/milestones

Objective 1: To understand the past drivers of food security at the household level in the Northern Uplands of Lao PDR

no.	activity	outputs/ milestones	completion date	comments
1.1	Collation and linkage of existing biophysical and socio-economic data	Biophysical dataset is collated and described	November 2016	The analysis of the soil data is presented in a project Discussion Paper, including methodology and possible extensions of this work – see Field and Odgers (2016), available at www.fsnu.info Data is also available on the same website
1.2	Identification of the hierarchy of drivers of food security	Statistical analysis of predictors of food security	February 2017	The analysis and conclusions are presented in McLeod and Santos (2020), an updated version of early analysis on which the project relied to guide the choice of interventions, which is not yet made publicly available.

Objective 2: To identify current constraints and opportunities to improvements in food security at household level in the Northern Uplands of Lao PDR

no.	activity	outputs/ milestones	completion date	Comments
2.1	Review of past and current interventions in the areas of food security	Evidence Gap Map	November 2016	Methodology, data and conclusions are presented in Leroux, Brown, McLeod and Xiong (2016).
2.2	Characterization of key agricultural markets	Analysis of market integration (consumer market)	October 2016	Methodology, data and analysis is presented in Nolan (2016).
2.2		Value-chain analysis of two main commodities (maize and cattle)	February 2017	Methodology, data and analysis is presented in Kousonsavath and Murray-Prior (2017).
2.2		Analysis of impacts of market regulation on producers' income	November 2019	The quantitative analysis of the impact of different forms of market regulation on producers' prices followed the results of the team fieldtrip and interviews with district and province officers, and the abandonment of the original proposal of conducting lab-in-the-field experiments on the effects of market regulation.
2.3	Identify opportunities and threats to food security at household level	Ethnographic analysis of the impact of market penetration on reciprocity, inequality and food insecurity	February 2017	Methodology, data and analysis is presented in Foale, Singthong and Latdanaphim (2017)

2.3		Analysis of non-income constraints to improvements in food security	April 2017	The analysis and conclusions are presented in Meyer et al (2017), which is not expected to be made publicly available soon. Leroux, Khuraijam and Phoddar (2020) further show that risk matters for livelihood choices, strengthening the case for insurance.

Objective 3: To implement and evaluate pilot interventions aimed at improving food security status of households.

no.	activity	outputs/ milestones	completion date	comments
3.1	Definition of evaluation strategies and design of pilot interventions	Project documents	October 2017	Unpublished documentation, included in outputs of the project (eg, information about power calculations, or appendices describing research protocols)
3.2	**Promoting a rodent contest to reduce post-harvest losses during the dry season**			
	Implementation of experimental design	Project documents	December 2017 – January 2018	Discussion with DAFO and village heads, randomised allocation of villages to treatment and control status
	Baseline Survey	Questionnaires	November - December 2017	
	Contest – first version	Payment to winners, conclusion of first contest	January 2018 – Pi Mai 2018	
	Follow-up survey	Questionnaires	May 2018	
	Qualitative analysis	Internal report	November 2018	
	Redefinition of contest		December 2018	Definition of prizes, following from preliminary analysis of household data and from qualitative analysis. Definition of additional villages to be included in study
	Follow-up survey	Questionnaire	December 2018	
	Contest – second version	Payment to winners, conclusion of second contest	January 2019 – Pi Mai 2019	
	Endline survey	Questionnaire	May 2019	
3.3	**Training cooperation to reduce rodent damage in the field during the wet season**			
	Definition of experimental protocols	Instructions for game, and follow-up discussions	April 2018	Published as appendices to Meyer, Santos and Yang (2021)

	Baseline survey	Questionnaires	May 2018	In conjunction with first follow up survey for activity 3.2
	Playing game in villages		May 2018	Research team
	Training on collective hunting		June 2018	In collaboration with DAFO Viengkham
	Organisation of collective hunting		July 2018	In collaboration with DAFO Viengkham
	Endline survey	Questionnaires	December 2018	In conjunction with first follow up survey for activity 3.2
3.4	**Demand Led Extension**			
	Presentation of intervention to province and district officials		February-March 2018	
	Baseline survey	Questionnaires	March 2018	
	Presentation of intervention to villages and definition of extension priorities		March 2018	
	Advertisement of extension needs		March –April 2018	
	Selection of trainers		April-May 2018	
	Disbursement of first grant		June 2018	Other grants followed every 6 months, subject to no evidence of misuse of the grant
	Follow-up on training sessions			Two province managers were employed by the project, and were in charge of Monitoring of these activities
	First follow-up survey	Questionnaires	December 2018	
	Endline survey	Questionnaires	November 2019	
3.5	**Studying the feasibility of index insurance for rice**			
	Definition of study		August 2018	
	Collection of NDVI data		August 2018	
	Definition of index and analysis of basis risk		January 2019	

7 Key results and discussion

7.1 Identifying constraints

7.1.1 What did we learn from reviewing past interventions?

Our search for relevant projects within the scope of the EGM review initially identified 198 projects, of which 121 were considered to be outside the scope of this review (common reasons for exclusion include: a national or regional focus, not specifically targeting the northern provinces; primarily focused on research or institutional change and policy making; focus on food aid; completed prior to 2005).

Of the 77 projects within scope, 6 projects were ongoing at the time of analysis. We were able to source sufficiently detailed final project or evaluation reports for 31 completed projects and mid-term reviews for an additional 4 completed projects. We also mapped 4 ongoing projects on the basis of their mid-term review reports. In total, 39 projects are summarized and mapped in the EGM.

An interactive version of the EGM was made available on the project website, allowing for the dissemination and wider use of this analysis and is presented in Figure 4. The EGM allows for a visual inspection of the number of projects that aim to address the particular food security outcome (via the size of the mark), the type of data on which the evaluation relies on and, consequently, the strength of the evidence presented (via the colour of the mark). Hyperlinks to the summaries of each project are accessible from this map. The EGM also has two filtering functions, one by food security pillar targeted, the other by province.

Size and nature of the evidence base

Of the 39 mapped projects, 24 collected some form of baseline data, but only one project used a counterfactual analysis to evaluate its impacts. A total of 15 projects relied on other types of data, including program inputs or intermediate outputs as opposed to project outcomes in their final assessment.

The mapping exercise translates into 800 mapped outcomes in the food security EGM. Of those, 4 outcomes are evaluated using a baseline and counterfactual. Around 27% of outcomes were evaluated against baseline data. This means that almost three quarters of reported outcomes cannot be compared against a baseline and less than 1% of outcomes are evaluated using a counterfactual. The implication for researchers and policy makers whose objective is to improve food security in the north is that the true impact of these projects on food security will not be known.

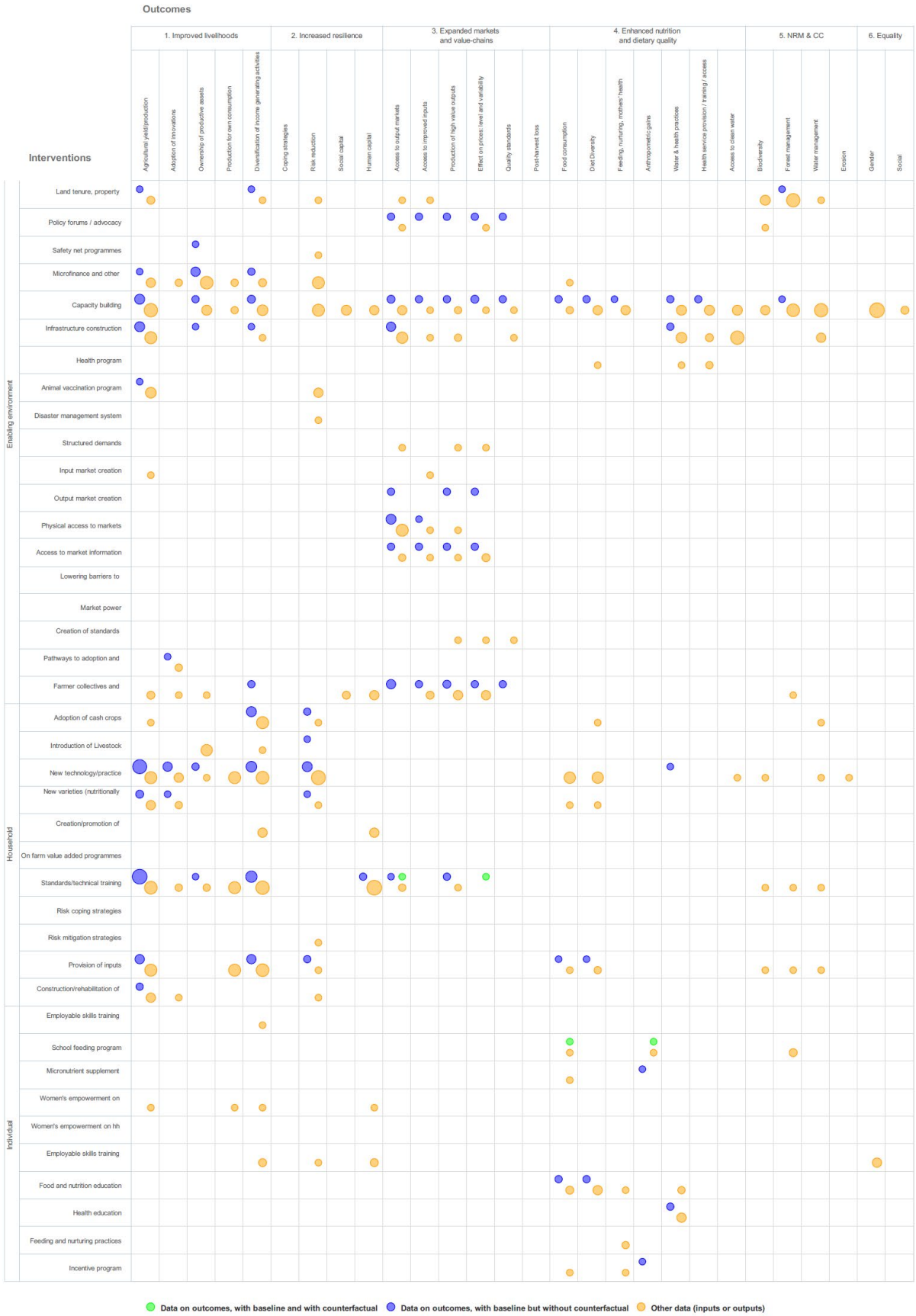


Figure 4: Evidence Gap Map: Food security in northern Lao PDR

Areas of intervention

A closer investigation of the distribution of interventions across the food security dimensions reveals that all six dimensions and almost all outcomes within each dimension were the target of some project intervention in recent years. Interventions that target capacity building at the enabling environment level have been implemented to increase capacity in each food security dimensions.

Certain focal points also become apparent upon closer examination of the EGM. Across the six dimensions of food security, improved livelihoods from agricultural activities and expanded markets and value-chains were targeted more often than other dimensions. This is in line with greater market access and better functioning of agricultural markets being key objectives for the Government of Laos (MAF 2010).

Within the dimension of improved livelihoods from agricultural activities, the majority of interventions had some enabling environment components often aimed at capacity building or increasing credit access in conjunction with households being introduced to new varieties or new technologies as well as receiving standards and technical training. Interventions that were aimed at expanding markets and value chains were more often concerned with improvements to the enabling environment, for example via infrastructure investments, creating physical market access and access to market information and establishing farmer collectives than they were with preparing individual households to be successful participants in markets.

A third dimension that was often targeted by food security interventions is enhanced nutrition and dietary quality. This occurred mainly at the enabling environment level, for example with interventions targeting capacity building and infrastructure development. This dimension was also the one that attracted most interventions that targeted the individual rather than the household via food and nutritional education programs for example.

Evidence Gaps

We distinguish between two types of evidence gaps: blank areas in the map and areas that have been targeted but where there is little information as to the success of the efforts.

In the food security EGM there are two blank areas. The first relates to risk coping strategies, where we found no intervention that specifically targeted strategies for communities and household to cope with negative shocks. This gap could potentially be important, given the possibility that exposure to uninsured shocks may be a source of poverty persistence. The second blank area gap in the EGM relates to post harvest losses.

The second type of evidence gap (derived from weak evidence), is of more general concern for the food security EGM. While the interventions that collected at least baseline data for comparison with end line data are concentrated within the improved livelihood and expanded market dimensions, almost none of the outcomes on natural resource management and equality can be compared against a baseline. As a result, answering the question of what has worked in terms of interventions targeting these two dimensions is near impossible.

In terms of evidence presented it is also surprising that only a small number of studies record and compare direct outcomes of food insecurity, such as, for example, anthropometric outcomes. Instead, many projects are evaluated based on more indirect measures of food security such as agricultural yield or household income, where the link between output and household food security is assumed rather than demonstrated.

7.1.2 How well integrated are consumer markets?

We used monthly price data by province capital city for up to 48 months from January 2011 to December 2014, focusing on the markets for paddy sticky rice, paddy steam rice, and first quality Lao sticky rice, Lao steam rice, beef, buffalo meat and pork. Data for some of these series are incomplete. For the majority of provinces the prices from January to April 2011 are not reported. We used imputation to fill missing values.

Using this data we perform Johansen co-integration tests to determine whether the markets in the city pairs (136 trace statistics/market pairs for each product, with the exception of pork, for which we only have 120 pairs, given lack of variation in Luang Prabang market) are cointegrated. The critical value to determine whether two markets are cointegrated is 15.41 (Osterwald-Lenum 1992), given the assumption that the VAR has an intercept. The number of markets found to be cointegrated for the seven commodity groups analysed is given in Table 2.

Table 2: Number and percentage share of integrated market pairs in Lao PDR

Food type	Number of market pairs integrated (out of 136)	Percentage of market pairs integrated
Paddy sticky rice	71	52.21
Paddy steam rice	43	31.62
Lao sticky rice 1	60	44.12
Lao steam rice 1	28	20.59
Beef 1	117	86.03
Pork 1	89*	74.17
Buffalo 1	115	84.56

Note: *There are only 120 market pairs for Pork

Two main conclusions emerged. Firstly, that the markets for the three livestock products tend to be integrated. Secondly, that the opposite is true for rice markets. The differences between commodities are consistent with Varela, Aldaz-Carroll and Iacovone (2013), who find that the degree of market integration varies across different commodities, although the results differ in that they find that the degree of integration for rice markets in Indonesia is greater for rice and sugar than for non-staple products such as soybeans and maize.

Determinants of market integration

To determine the factors which influence the extent of market integration, we regress the trace statistics for pairs of provincial capitals (generated in the first step, above), on variables, measured at provincial level, that proxy for transaction costs, market infrastructure, technology adoption, and demand (population and income). A summary of the results for the seven food groups is shown in Table 3.

Table 3: Explaining market integration in northern Lao PDR

	Paddy sticky rice	Lao sticky rice	Paddy steam rice	Lao steam rice	Beef	Buffalo	Pork
	Whether or not statistically significant						
Transaction costs							
Travel time between provincial capitals	No	Yes (-ve)	No	No	No	No	Yes (-ve)
Geographic factors							
% villages urban	No	No	No	No	No	No	No
% HH upland	Yes (+ve)	No	Yes (+ve)	No	Yes (+ve)	No	No
% rural villages prone to natural disasters	No	No	Yes (+ve)	Yes (+ve)	Yes (+ve)	No	No
Market infrastructure							
Paved road density percent	Yes (+ve)	Yes (+ve)	Yes (+ve)	Yes (+ve)	No	No	No
% of popn exposure to all three media	Yes (-ve)	No	Yes (-ve)	No	Yes (-ve)	No	No
% villages with Credit facilities	No	No	Yes (+ve)	No	No	No	No
% of villages in which ag produce sold	Yes (-ve)	Yes (+ve)	Yes (-ve)	No	Yes (+ve)	No	No
Adoption of technology							
% HH using rice mill	Yes (+ve)	Yes (+ve)	Yes (+ve)	No	Yes (-ve)	No	No
% area planted to improved rice varieties	Yes (-ve)	No	Yes (-ve)	Yes (-ve)	Yes (+ve)	Yes (+ve)	No
% of villages with electricity	No	Yes (-ve)	No	Yes (+ve)	Yes (+ve)	Yes (-ve)	Yes (+ve)
Demand							
Total population of province	Yes (0)	Yes (0)	No	No	No	No	No
Supply							
Commodity production per capita	Yes (-ve)	Yes (+ve)	No	No	Yes (-ve)	No	No
Commodity production per capita squared	Yes (0)	No	Yes (0)	No	Yes (+ve)	No	No
F Stat of regression	20.450	15.320	18.620	14.470	6.160	7.480	3.430
Prob > F	0.000	0.000	0.000	0.000	0.000	0.000	0.000
R squared	0.743	0.720	0.613	0.590	0.550	0.602	0.446

Notes: Yes/No stand for statistically significant/insignificant effect, respectively. (+ve), (-ve) and (0) stand for economical positive, negative or insignificant effects, respectively.

The results were obtained by estimating regressions including data for both provinces in the respective pairs, and then estimating the joint effects for each characteristic, with the exception of time taken to travel between the provincial capitals. The reported values are the joint effects. Because we have considered that there may be correlation between the four different rice markets we have also included estimates using Seemingly Unrelated Regressions. While we can reject the null hypothesis that the markets are independent, the degree of correlation is minor, and has a minimal effect on results.

The factors that have a statistically significant effect on market integration differ across food products, and are summarised in terms of whether they are significant, and whether they have a positive or negative effect. The models for the four rice markets are better in terms of overall significance and goodness of fit than those for meat.

Travel time between provincial capitals is statistically significant only for Lao sticky rice and for pork, and has the expected negative sign. Some variables have no statistical significance in explaining market integration, or have surprising signs, and this may relate to the fact that we are using prices in provincial capitals, not disaggregated price data from villages, and also that our independent variables are average provincial data. This problem applies particularly to the geographic factors. For example, the percentage of villages in a province that are urban has no statistically significant effect on market integration. The percentage of villages in a province that are upland has a positive statistically significant effect for both types of paddy rice, and for beef, and the percentage of villages prone to natural disasters has a positive statistically significant effect for paddy and Lao steam rice, and for beef. Results for the market infrastructure variables are also mixed. The paved road

density has, as expected, a statistically significant and positive effect on market integration for all rice categories, but no effect for meat markets. The percentage of the provincial population with good exposure to the media has surprisingly a negative effect, and the percentage of villages with credit facilities has an effect (positive) only for paddy steam rice. The percentage of villages with a market (that is, where agricultural produce is sold) has a negative effect for paddy rice, and positive effect for Lao sticky rice and for beef.

7.1.3 Income and food security at household level

McLeod and Santos (2017) present the results of the analysis of the prevalence and correlates of food security using the two representative datasets described in section 5.1.2. Here we present their main conclusions:

- Food insecurity did not significantly change between 2008 and 2013
- Food insecurity is significantly more important when focusing on micronutrient deficiency or anthropometric indicators, likely reflecting a diet that is not sufficiently diversified, than when focusing on macronutrients (calories or protein)
- Seasonality matters to explain food insecurity measured in terms of prevalence of diet diversity, with suggestive consequences for the nutritional status of very your children
- The effect of income is more heterogeneous than previously assumed, with positive impacts in terms of reducing the prevalence of food insecurity but this effect is moderated by access to better infrastructure (all-year roads and, with them, markets).

Quantifying food insecurity at household level

We begin our quantitative analysis of Food Insecurity by presenting, in Table 4, the standard definitions of the different deficiency thresholds that we analyse. In Table 5, we then present information regarding the prevalence of Food Insecurity, measured across these indicators: energy deficiency (an indicator of diet quantity), micronutrient and macronutrient deficiency (indicators of diet quality and quantity), the Food Consumption Score (FCS) (an indicator of diet quality), and a number of malnutrition indicators (height for age z-scores representing stunting, an indicator of chronic malnutrition; weight for age z-scores representing wasting, an indicator of acute malnutrition; weight for height z-scores representing underweight, an composite measure of both acute and chronic malnutrition) both for the rural parts of the country as a whole and conditional on region and strata relevant to rural areas, namely, with and without road access.

Table 4: Deficiency thresholds, by indicator

Indicator	Threshold
Energy deficient	<2600 calories
Protein deficient	<56 grams
Carbohydrate deficient	<100 grams
Iron deficient	<8 milligrams
Vitamin A deficient	<900 micrograms
Zinc deficient	<11 milligrams
Poor and borderline food consumption - FCS	<36
Moderately or severely malnourished - HAZ	<-2
Moderately or severely malnourished - WAZ	<-2
Moderately or severely malnourished - WHZ	<-2

Source: Energy, micronutrient and macronutrient, and malnutrition thresholds were adopted from the IFPRI survey expenditure handbook, the Dietary Reference Intakes produced by the Food and Nutrition Board, Institute of Medicine, National Academies, and Shively & Sununtnasuk (2016) respectively.

We make two comments about the indicators chosen. Firstly, we note that we do not present descriptive statistics of prevalence of overweight. This omission is deliberate, and reflects the specific objective of this analysis, in particular its focus in establishing a relation between agricultural production and food insecurity. Secondly, we note that the method we use to quantify food insecurity is likely to result in a lower bound estimate for two reasons: our estimates of nutrient consumption are in fact estimates of nutrient availability, and we equate the diet adequacy of individuals with the average diet adequacy of the household they belong to, neglecting the importance of intrahousehold inequality in access to food (Haddad & Kanbur, 1990).

The prevalence of food insecurity did not change between 2008 and 2013

Several conclusions emerge from Table 5. The first conclusion is that the prevalence of food security does not seem to change much between 2007 and 2012, for all indicators, except for the FCS: at the rural level, approximately 1 in 7 households consume less energy than necessary in both 2007 and 2012. At the rural level, approximately 1 in 3 households are classified as poor and borderline food insecure in terms of their overall diet (as measured by the FCS) in 2007, and that percentage increases significantly in 2012.

These general findings about rural areas of Lao PDR hold when we separately focus on the different regions and for rural areas with road access. However, there appear to be noticeable negative changes in most indicators in rural areas without road access.

Table XXX: Frequency of food insecurity in rural Lao PDR, region and strata

	Year	Rural Lao PDR	North	Central	South	Rural, with road	Rural, without road
Calorie deficient	2008	15%	13%	13%	17%	15%	11%
Calorie deficient	2013	14%	10%	16%	17%	14%	17%
Protein deficient	2008	3%	3%	2%	4%	3%	2%
Protein deficient	2013	3%	2%	6%	2%	3%	10%
Carbohydrate deficient	2008	1%	0%	3%	2%	2%	0%
Carbohydrate deficient	2013	2%	0%	6%	2%	2%	1%
Iron deficient	2008	16%	10%	17%	20%	16%	14%
Iron deficient	2013	16%	11%	19%	18%	16%	13%
Vitamin A deficient	2008	81%	71%	90%	84%	81%	75%
Vitamin A deficient	2013	83%	68%	93%	88%	83%	81%
Zinc deficient	2008	14%	15%	10%	16%	14%	14%
Zinc deficient	2013	13%	11%	15%	13%	12%	20%
Poor and borderline food consumption - FCS	2008	37%	55%	13%	33%	36%	41%
Poor and borderline food consumption - FCS	2013	45%	55%	33%	44%	44%	59%
Moderately or severely malnourished - HAZ	2012	59%	67%	61%	52%	58%	69%
Moderately or severely malnourished - WAZ	2012	36%	35%	47%	31%	36%	41%
Moderately or severely malnourished - WHZ	2012	7%	7%	10%	6%	7%	7%

Source: Based on own calculations using data from LECS4, LECS 5 and LSIS. Note that LSIS does not have the same data as LECS, hence the missing values. Frequencies derived from LECS data are in terms of households with inadequacy in an indicator while frequencies derived from LSIS data are in terms of children with inadequacy in an indicator.

The second conclusion is that although the prevalence of energy deficiency is significant, other macronutrient deficiencies are low: for example, only 3% of the rural population consumes less protein than recommended in 2012, while only 2% consume less carbohydrates than what is recommended.

The third conclusion is that the prevalence of macronutrient deficiency is dwarfed by the prevalence of deficiencies in the consumption of micronutrients: for example, in 2012 83% of the rural population consumes less vitamin A than what is recommended, while the prevalence of iron and zinc deficiency is approximately equivalent to that of energy deficiency. It is important here not to fall in a language trap: iron, zinc and vitamin A are micronutrients because they only need to be consumed in small amounts, not because they are less important than energy, protein, carbohydrates or fat.

Finally, and reflecting these conclusions, the correlations between different indicators range from weak to moderate, in both waves of LECS: the highest association (approximately 0.6) is between calorie deficiency and zinc deficiency, while other correlations (including with either vitamin A or the food consumption score) appear to be quite low. Clearly, reducing energy deficiency or simply increasing diet variety as measured by the FCS does not seem sufficient to reduce other deficiencies.

Before we move to an exploration of the determinants of food insecurity using multivariate regression, we make one further remark. We can take advantage of the fact that LECS was fielded throughout the year (with similar numbers of households interviewed in each month) to quantify the importance of seasonality in the prevalence of food insecurity. Figure 5 presents the frequency of food insecurity, measured in terms of poor or borderline food consumption (FCS), in rural areas of Northern Laos, for the two sampling strata (with and without roads). Another interesting observation, is that the incidence of poor diet quality (as measured by the Food Consumption Score) seems to peak in the months before the new harvest (and presumably in tandem with the exhausting of rice stocks, at least for some households), especially for rural areas without road access. The reason for this pattern is not completely clear, although one possible explanation is that given higher rice prices in villages without access to road as stocks get exhausted (see the analysis in section 7.1.2), households reduce their consumption of richer (and more expensive) foodstuff in order to consume cheaper (but increasingly more expensive) calories.

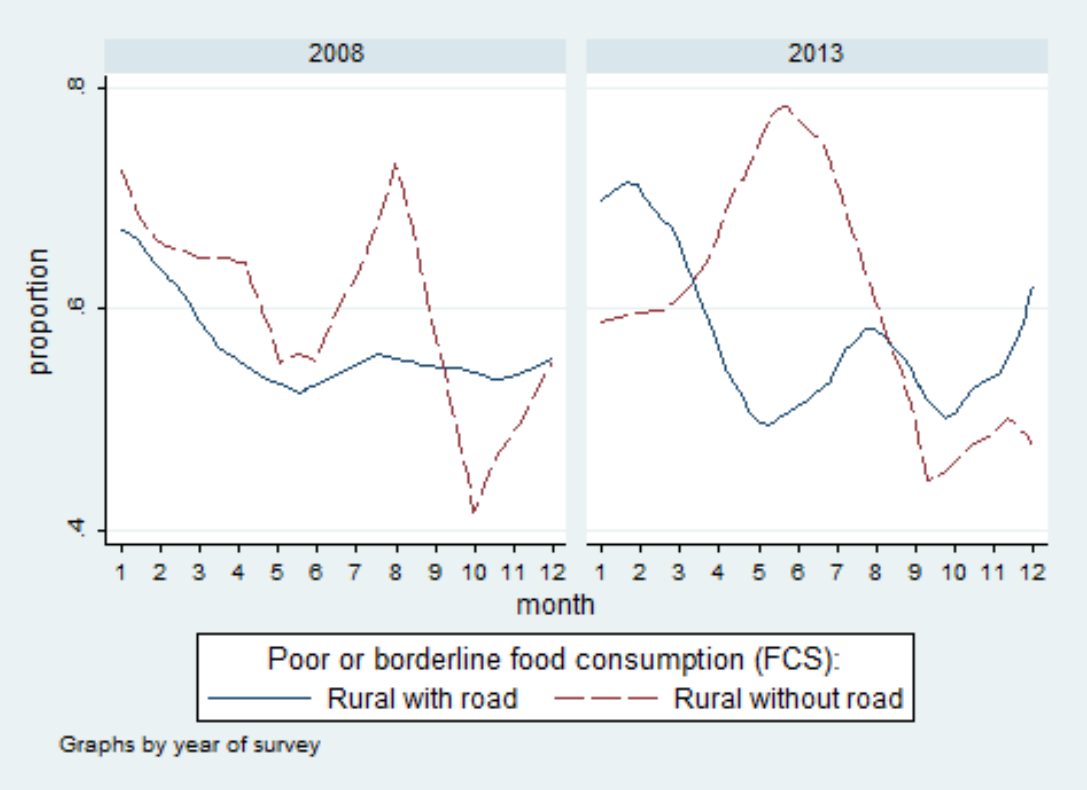


Figure 5: Proportion of FCS deficient households, Northern Laos

It is possible that, as in other contexts, such differences in seasonal access to food have long-term consequences in terms of malnutrition. Seasonality in food consumption can influence maternal nutrition intake, affecting prenatal development and subsequent birth outcomes. This hypothesis seems to find some support in the data, as shown in figure 6, where we present the proportion of children in rural Northern Laos that are moderately or severely malnourished (as measured by the HAZ).

It is evident that the prevalence of malnutrition is at its highest for children born in the early months of the year. Notably, children in rural areas without road, that are born at the beginning of the year, are developing in the womb when the incidence of poor diet quality and energy deficiency, as evident in Figure 6 during months 5 - 10, is at its highest. Unfortunately, it is impossible to identify this link as causal given the independence of LECS and LSIS. Further limitations of the data available (in particular the lack of panel data on child growth) prevents us from understanding whether such initial shocks have persistent effects although, as shown in the same figure, the frequency of malnutrition seems higher for children born earlier in the year (when compared with being born in the second half of the year), regardless of age.

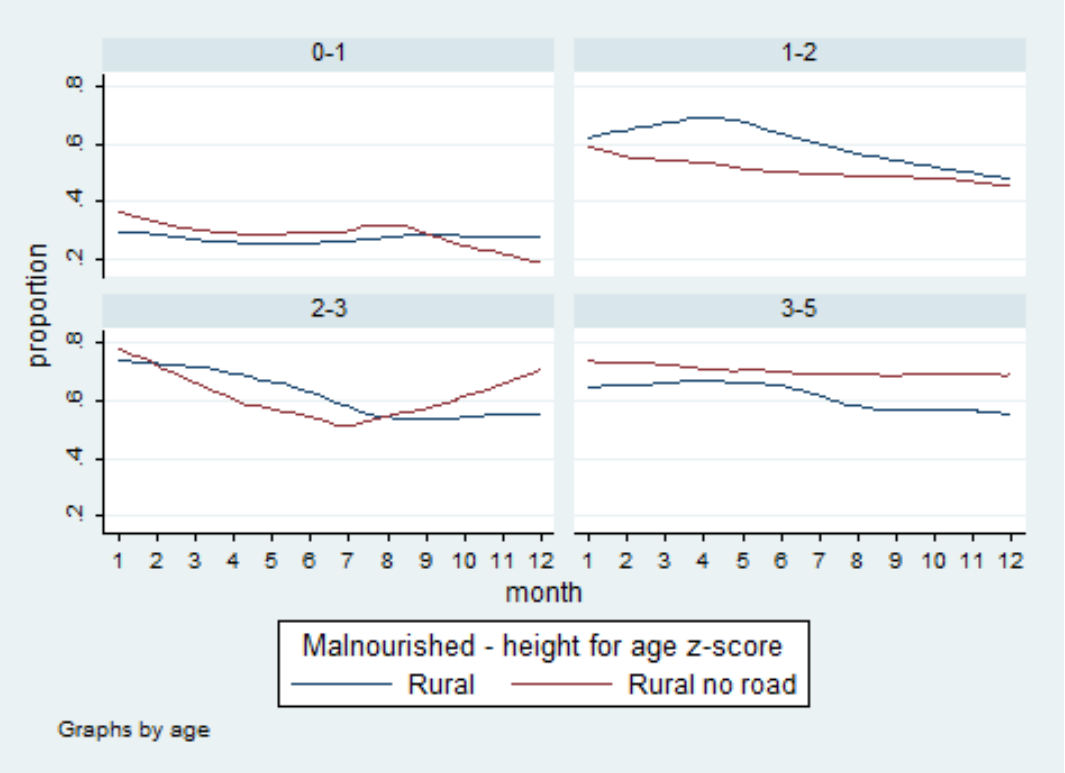


Figure 6: Proportion of malnourished children (HAZ<-2), northern Laos, by age group.

Multivariate analysis of the correlates of food insecurity

Table 6 presents the results of the multivariate regression analysis of food insecurity (an indicator variable that takes the value of 1 if the household is classified as food insecure on the basis of its FCS) as a linear function of household and village characteristics, and separately considering villages with and without access to all-year-round roads. Contrary to earlier, and more aggregate, analyses (to which we referred to, when discussing the motivation of this project), the analysis of micro-data suggests that higher income does translate into reductions in food insecurity *when households have access to infrastructure (roads):* an increase in household income of approximately AU$1,700 (at the 2018 exchange rate) reduces the probability of having a poor diet by approximately 4% (approximately 10% of the unconditional mean, presented above). Our analysis also shows that this effect is not particularly heterogeneous with respect to the household position in the income distribution (ie, poorer households, in the lowest quartile of income earners, behave similarly to richer households), and seems to be driven by livestock sales (more than crop sales). Finally, our analysis seems to suggest that households that do not rely on agricultural production are much less likely to be food insecure (possibly reflecting more remunerative livelihood options).

Our analysis also shows that, in the absence of access to roads, income does not seem to have any effect of the likelihood of being food insecure, possibly because access to food through markets is not possible. Supporting this interpretation, addressing seasonality is much more important in increasing food insecurity in this subsample.

Table 6: Food insecurity: the importance of income

	North, rural, with roads			North, rural, without roads		
Variables	(1)	(2)	(3)	(4)	(5)	(6)
Wet season	0.120**	0.119**	0.093*	0.410***	0.429***	0.465**
	(0.051)	(0.051)	(0.052)	(0.149)	(0.149)	(0.189)
All Income (tens of million)	-0.038***	-0.037***		0.000	0.003	
	(0.008)	(0.008)		(0.017)	(0.017)	
1st quartile income earners=1 # All Income (tens of million)		0.056			0.430	
		(0.160)			(0.425)	
Income - labour & transfers			0.054			0.992
			(0.126)			(1.161)
Value of crop sales (tens of million)			-0.022**			0.203***
			(0.011)			(0.061)
Value of livestock sales (tens of million)			-0.046***			-0.013
			(0.011)			(0.015)
Value of forest product sales (tens of million)			-0.066			-0.150
			(0.048)			(0.251)
Value of fish sales (tens of million)			0.011			-0.131
			(0.039)			(0.150)
Does not produce crops			-0.430***			0.541
			(0.165)			(0.414)
Does not produce livestock			-0.129**			0.299
			(0.063)			(0.219)
Livestock Sale Diversity Index			0.035			0.312
			(0.083)			(0.261)
Crop Sale Diversity Index			-0.251**			0.719**
			(0.119)			(0.356)
Constant	0.627**	0.614**	0.722**	0.950**	0.937**	0.741
	(0.286)	(0.287)	(0.326)	(0.382)	(0.380)	(0.469)
R-squared	0.079	0.079	0.110	0.131	0.136	0.242
N	1056	1056	1056	200	200	200

Note: additional variables include household characteristics (dependency ratio and household head characteristics such as sex, age, marital status, ethnicity and education), village characteristics (frequency of local markets, altitude and distance to road), a yearly dummy (=1 if data collected in 2013)

7.1.4 What are the main constraints to the development of maize and cattle value-chains?

Kousonsavath and Murray-Prior (2017) present the results of the analysis of the value chains of maize and cattle in the four districts in which primary data was collected. Here, we present only a summary of the main conclusions.

Mediocre productivity maize chains

Maize was widely grown, but apart from Kham district where most households sold their grain to traders, it was not a major source of income. It was grown mostly in the wet season without irrigation. Productivity as measured by yield was much higher in Kham than in the other three districts, and this appears to be related to greater use of inputs. However, even here yields are below potential. Key constraints in the cropping systems leading to the low yields included: lack of irrigation, outdated cropping systems, possibly poor knowledge and skills of farmers in intensive maize production systems.

These constraints were accentuated by difficulty obtaining key inputs, poor management and arm's-length marketing relationships, with farmers having little knowledge of the markets for their products. There was little horizontal and vertical coordination in the chain, due to insufficient support from the grain buyers and RD&E sectors. A lack of horizontal coordination limits the ability of farmers to benefit from cooperation, e.g. in input supply, information and bulking up of grain.

Overcoming these issues would require a greater focus on the whole agribusiness systems for crops including the enabling environment and improving the ability of chains to produce higher value product. Potential improvements include: irrigation, drying and storage infrastructure, better and more information on intensive cropping systems that include maize in the cropping rotation, availability of both variable inputs (such as fertiliser) and capital inputs (such as planting machinery), standards and regulations around grain marketing, farmer knowledge and ability to measure moisture and grain quality, availability of price information, business skills, access to finance accounts and credit, and encouragement and support for farmer groups.

Further work is required on the reasons for the problems underlying poor input supply, access to finance accounts credit and information services and solutions to these problems. However, improvements need to take a systems approach as improvement to one of the constraints may not produce substantial improvements without other constraints being improved also.

Low productivity cattle chains

The cattle farming system relies on minimal-management grazing of cattle on land not used for cropping. However, it provides considerably more income than maize for households who have cattle in Pak Xieng, Viengkham and Phoukout districts, but not in Kham district. Due to the small herd sizes, only small numbers of marketable cattle are available at any one time and hence smallholders are not in a good negotiating position when it comes to selling cattle. No information was available on herding systems, stocking rates, growth rates, mating practices and times, and very little information was collected on calving practices, mortality rates and animal health practices, so it is not possible to directly measure productivity. However, the evidence from the literature and this study supports the view that productivity is low.

Key constraints in the cattle chain contributing to low productivity include: low productivity herds due to poor feeding, breeding and herd health management, difficulty obtaining key inputs and services, poor knowledge and skills in cattle management, lack of market standards and

inconsistent regulations, poorly developed supply chains, lack of good information about prices and demand.

The lack of an effective cattle chain and a low productivity production system means that Laos is used by Vietnam and China as a gap-filler, which is facing increasing competition from other countries, such as Australia. This will constrain the cattle industry until it can begin to produce large numbers of consistent quality cattle that meet the requirements of their market.

Cross-cutting constraints in the enabling environment

In this study some cross-cutting constraints were identified that reduce the efficiency and effectiveness of all agricultural supply chains, but are also important to the maize and cattle supply chains. They include: poor roads, irrigation and storage infrastructure in some districts, a lack or irregular transport services to many villages that inhibits purchase of inputs and sale of products, constraints on access and availability of savings accounts and credit, and lack of business development services.

In addition to government policies already in place to address some of these issues, Kousonsavath and Murray-Prior (2017) suggest that there are opportunities to enhance them, including:

- Women have a major role in production and decision making so there should be a focus on improving their knowledge and skills and targets should be implemented for their involvement in all development and extension activities.
- There is a high penetration of mobile phones that may be used to provide simple ICT services.
- Many farmers already have savings accounts or obtain credit from formal sources, creating the potential to alleviate constraints to the expansion of these services and develop strategies to increase their adoption.
- Develop policies to promote the provision and use of business development services throughout the maize and cattle chains.
- Make better use of farmer groups for research, extension and development activities.
- Provincial government should work with local governments to decrease the transaction costs and market distortions associated with the inconsistent and multiple levels of taxation, regulations and permits required to conduct business.

However, Kousonsavath and Murray-Prior (2017) offered no directly implementable interventions that could be feasibly implemented in the context of this project, particularly if informed by a value-chain perspective. That said, several suggestions were taken, on a piecemeal basis, by producers themselves, as part of the Demand-Led Extension approach that we piloted, suggesting that they were potentially valued by their potential beneficiaries.

7.1.5 Kinship, reciprocity, inequality and food security: a qualitative study of four villages in northern Lao PDR

In addition to the household and trader survey that supported the conclusions just presented, the project conducted an in-depth analysis of the impacts of commercialization of agricultural production of norms of reciprocity.The key hypothesis driving this work was that if increased market engagement had eroded social ties by making people more individualistic in orientation and by increasing inequality, then food security might be affected negatively through the weakening of traditional social support systems, which people traditionally relied on during hard times that are widely believed to matter to reduce vulnerability to food insecurity. Foale, Singthong and Ladtanaphim (2017) present the results of this analysis, conducted in four villages, and offer the following broad conclusions:

1. At the time of fieldwork, maize production has been substantially reduced in all three villages where it had been a significant cash earner in the past ten years. The main reasons appear to be low prices, decreased quality and soil degradation.

2. Three villages have increased cattle production and one (Khaivieng) is increasing production of watermelons.

3. Systems of informal reciprocity are present in all villages and are healthy, and apparently even stronger than in the past in Hat Pha Ot and Khaivieng, but perhaps eroding somewhat for Phou Nor Wan and Ban Huat. Labour appears to be commonly exchanged informally, as well as formally (i.e. for cash).

4. Rice banks are reported for Hat Pha Ot, Khaiveng and Huat villages. There are village micro finance groups (Kong Theun Ban) in Hat Pha Ot, Phounorwan and Khaivieng. Borrowing from relatives is also common in all villages.

5. The data does not indicate a particularly uniform correlation between a) increased engagement with markets and increased inequality, and b) increased inequality and decreased social support. However inequality appears to have increased in some of the villages, mainly as a result of rapid increases in both income and land ownership for some households due to success with commercial farming.

6. None of the householders the team spoke to reported any decrease in food security that could be attributed to negative social changes driven by increased market engagement.

The authors do note, however, that the history of integration with the market is relatively short, preventing them from being more conclusive about any effect of increased commercialisation on inequality and social cohesion. In any case, and contrary to the initial hypothesis that guided this work, it became clear that issues of increased inequality driving increased food insecurity were perhaps less important than originally assumed.

7.1.6 Looking beyond income – I : losses, gender and behavioural aspects of food insecurity

The analysis presented in Section 7.1.3 focused on the importance of “traditional” determinants of food insecurity, building on the extensive literature that explores the importance of the “access pillar” (Sen (1981); see Barrett (2001), for a still relevant summary of this work). Surveys such as LECS do not allow us to incorporate more recent developments in the analysis of food security that emphasizes the importance of intrahousehold bargaining, limited self-control and mental accounting.

To quantify the importance of these determinants of food security, we collected original household survey data in 30 villages in four districts (two in each province), totalling 270 households. The survey has three components: a household head survey, a spouse survey and a village survey. The modules of the surveys cover household demographics, livelihoods and assets (with a special focus on labour allocation and agricultural production), food insecurity and behavioural determinants of decision (preferences towards risk, ambiguity and time, self-control, competitiveness).

Food insecurity is measured using the Food Consumption Score (FCS), as calibrated to the food consumption patterns in Lao PDR (WFP, 2007). As predictors, we included a large set of variables, including labour availability (number of household members between 18 and 60 years), dependency ratio (number of dependents per labour force in a household), asset index for durables (ownership of six different durables, such as TV, refrigerator or cell phone), housing

(quality of housing according to variables such as type of roof, floor or walls). In addition to these variables, we were mostly interested in those that were included to measure predictors of food security for which we did not have information in the nationally representative surveys: the importance of women as decision makers in the household (the number of decisions, out of 14 possible decisions, in areas covering agriculture, family and social interaction, that are made by women either alone or jointly with their spouse), self-control index (constructed using the measure developed by Tangney et al (2004) and collected for both the household head and the spouse), and detailed information about shocks, both at community and household level (specifically, drought and losses to rodents).

Table 7 presents the results of the OLS regression of FCS on these explanatory variables. The full model is presented in column (1), while in columns (2) and (3) we exclude Self-Control Indices and the number of decisions a woman is involved, respectively, given the importance of multicollinearity between these two variables (which prevent us from identifying the individual importance of each variable).

The variables that significantly affect food insecurity are wealth (proxied by asset indices, but not by ownership of livestock or land), involvement in outside income earning activities (handicrafts, but not wage labour), shocks (drought and post-harvest losses of rice) and the male self-control index. When this variable is excluded (column (2)), the Women Decision Maker variable becomes significant. The interpretation of this result is that decision making in the household has an influence on food security. As women self-control and the number of decisions that a woman is involved are collinear, their separate effect cannot be precisely identified in the results presented in column (1). Whereas the literature on self-control in developing countries is scarce, the effect of Women Decision Maker is in line with earlier research.

Table 7: Food insecurity: the importance of non-income explanations

	(1)	(2)	(3)
	Food Insecurity	Food Insecurity	Food Insecurity
Labour force	0.008	0.004	0.011
	(0.017)	(0.017)	(0.017)
Dependency ratio	-0.009	-0.002	-0.009
	(0.020)	(0.020)	(0.020)
Asset index: durables	-0.113***	-0.102***	-0.114***
	(0.030)	(0.031)	(0.030)
Asset index: housing	-0.060**	-0.070***	-0.058**
	(0.027)	(0.027)	(0.027)
Land (in ha)	-0.005	-0.006	-0.007
	(0.010)	(0.011)	(0.010)
Livestock (number)	-0.001	0.000	-0.001
	(0.004)	(0.004)	(0.004)
Women power (# decisions)	-0.008	-0.011*	
	(0.006)	(0.006)	
SC index, male	-0.147***		-0.155***
	(0.047)		(0.046)
SC index, female	-0.087		-0.089
	(0.054)		(0.054)
Drought	0.097*	0.088*	0.090*
	(0.050)	(0.052)	(0.050)
Catches/produces fish	-0.007	-0.008	0.002
	(0.053)	(0.053)	(0.052)
Involved in casual labor	0.061	0.073	0.060
	(0.063)	(0.064)	(0.063)
Involved in formal labor	-0.003	-0.041	-0.001
	(0.061)	(0.061)	(0.061)
Involved in business	0.057	0.031	0.060
	(0.081)	(0.083)	(0.081)
Involved in handicrafts	-0.139**	-0.144**	-0.149**
	(0.061)	(0.063)	(0.061)
Collection of NTFP	-0.067	-0.069	-0.056
	(0.055)	(0.056)	(0.054)
Receives remittances	0.164	0.140	0.147
	(0.107)	(0.109)	(0.106)
Post-harvest losses due to rodents (in %)	0.008**	0.009***	0.008**
	(0.003)	(0.003)	(0.003)
Constant	1.284***	0.403*	1.220***
	(0.320)	(0.207)	(0.317)
R-sqr	0.31	0.27	0.31
N	267	267	267

Notes: Values within parenthesis are standard errors. * p<0.10, ** p<0.05, *** p<0.01. Additional controls include demographic characteristics of household head and indicators of agricultural production.

7.1.7 Looking beyond income – II: soils and biodiversity

An emerging literature emphasizes the importance of natural capital (fertile soil, adequate access to water resources, biodiversity) on living standards in developing countries, particularly for the poor. In this project we explored two possible mechanisms through which such effect may manifest itself: soil quality may create the conditions for poverty persistence (see Barrett and Bevis (2018)) and biodiversity conservation may lead to improvements in wellbeing.

McLeod and Santos (2020) use the data on soil characteristics produced by this project (described in section 5.1.2), together with data on consumption poverty from LECS5, to estimate the relation between soil characteristics and poverty. They argue that, because soil characteristics are predicted estimates, concerns of reverse causality that plague this literature are less important and that the resulting estimates are plausibly causal. The main result (that lower soil acidity reduces poverty) is perhaps unsurprising but a discussion of mechanisms suggests that soil characteristics do not seem to act via differences in agricultural productivity, suggesting that alternative routes (eg, past levels of investment in infrastructure) may be at play.

Butorac (2018) uses a matching estimator to quantify the causal impact of ComFishIII, a freshwater fisheries conservation program implemented by WWF-Laos on biodiversity. The program is shown to lead to large increases in species richness. More speculatively, Butorac, Santos, Phouvin and Guegan (2019) expand this analysis to quantify the impact of such increase in biodiversity on human outcomes (child malnutrition). Although the effect is large, data limitations prevent a causal interpretation of the estimates.

7.1.8 Income risk, livelihood choices and food security

A large literature emphasises the link between the importance of uninsured risk and low levels of wellbeing (including food insecurity). Leroux, Khuraijam and Phoddar (2020) investigate this link by examining the degree of risk exposure and the livelihood portfolio choices (the mix of income-generating and subsistence type household activities) of food secure and food insecure households. Using insights from finance they develop a theoretical model to characterize optimal livelihood portfolio choices across key productive activities that are subject to risk so as to maximise household consumption above a wellbeing threshold, i.e. the food security threshold. In addition to return risk from yield and price fluctuations the authors also consider the effect of utility risk (life events, health crisis) on optimal portfolio choice. It is shown that choosing lower risk and lower return portfolios can be an optimal strategy to mitigate utility risk for households that are vulnerable to food insecurity.

Using the data described in section 7.1.6, they show that households' livelihood portfolios are complex: the average household engaged in five different activities (with a minimum of three and a maximum of seven). A deeper analysis of the trade-offs involved in the allocation of land between cash crops (maize) and food crops (rice) confirms the theoretical predictions, revealing that severely food insecure households allocate a greater share of land to the production of food than food secure households

This result suggests that households consider their vulnerability to subsistence thresholds when deciding on their livelihood portfolio. Although there are no claims of causality in the empirical analysis, this conclusion further strengthens the evidence supporting the potential role of insurance as a policy to support the commercialisation strategy implemented by the government of Lao PDR. In its absence, more vulnerable households will likely self-select themselves out of new market opportunities due to risk considerations.

7.2 Selecting pilot interventions

The general approach to the selection of pilot interventions was presented in Section 5.2. Following the initial diagnostic work, described in Sections 5.1 and 7.1, we identified six potential interventions, addressing different causes of food insecurity. They are described next.

1. Reducing post-harvest losses through rodent control (Cause of Food Insecurity to be addressed: Post-harvest losses)

As with other pests, the success of any intervention directed at reducing rodent pressure rests on being able to overcome the free-rider problem: each individual farmer benefits from their neighbours' efforts and has an incentive to let them dedicate time and effort to this task, while devoting his time to activities that exclusively benefit his household. The key to increase the effectiveness of this type of interventions is to design ways to encourage a large number of households in a village to participate (FAO, 1994).

We proposed that a rodent culling contest, organised at local level, with prizes to be paid to those households that cull most rats could potentially reduce the value of unpaid externalities generated by individual rodent control. This type of intervention is simple, requires very low investments by participating households (traps are commonly known and inexpensive) and can potentially be complemented by other, more complex, interventions – for example, pre-harvest community control mechanisms (e.g. ecologically based rodent management) that require community activities (e.g. community coordinated hunting) or minor modification of the granaries to limit the access of rodents to stored grain. A practical implementation of this approach would require the definition of the optimal level of prizes, as well as ways to define cost-effective ways to monitor its functioning.

2. Increasing competition in livestock trade (Cause of Food Insecurity to be addressed: Depressed livestock prices)

Livestock, and in particular cattle/buffalo, is a major opportunity for income generation for agricultural households in northern Lao PDR, benefiting from close proximity to large foreign markets (particularly China, but also Vietnam). Translating this increased demand into income requires a well-functioning marketing system. Anecdotic evidence and the analysis of the cattle value chain conducted during the diagnostic phase (complemented, later in the project, by more solid quantitative analysis) pointed to the importance of regulatory restrictions to competition in allowing markets to fulfil this role.

We proposed two ways to potentially improve livestock producers' access to markets and their bargaining power: (1) to enable/organise cattle groups to become active as livestock traders, and (2) an information system for livestock prices for smallholder farmers.

3. Developing an index-based insurance for rice in northern Lao PDR (Cause of Food Insecurity to be addressed: drought shocks)

The limits of traditional coping strategies as ways to address covariate shocks such as extreme weather shocks (in northern Lao PDR, mostly drought) are well known in the literature. Traditional solutions, relying on multiperil insurance, also have known limitations, including problems of asymmetric information and the associated high transactions costs.

A potential solution is the development of index-based weather insurance, already implemented in several developing countries. The payouts of this financial product depend on an observable index (e.g. aggregate rainfall in a given time or days without rain). Compared to traditional agricultural insurance, index insurance addresses the problems of adverse selection and moral

hazard as well as those associated with high transaction costs, but at the cost of introducing an additional source of risk: the lack of perfect correlation between the index (used to estimate losses, on which contracts are defined) and real losses, also known as basis risk.

4. Addressing self-control to increase food security (Cause of Food Insecurity to be addressed: Lack of self-control)

Self-control is a psychological concept that captures individual capacity to resist temptations (or stick to plans in order to achieve individual goals) when making decisions. A person without self-control will act as if preferring short term benefits over long term benefits, even if they state that they would prefer the latter. For instance, a person would not easily finish tasks, or spend money on goods that they would regret having bought later.

A potential intervention could consist of two components: (1) creating habits of setting daily goals and reflecting, at the end of a day, whether they were achieved (or not, and why) and (2) promoting information about the experiences of successful peers.

5. Time-saving intervention for women (Cause of Food Insecurity to be addressed: Low involvement of women in household decision making)

Socio-cultural norms divide activities within households by gender. Female work categories are mostly time consuming and not income oriented (e.g. household chores, firewood collection, etc.). Promoting tools that reduce women's time burden, female household members can become more active in income generation. Economic empowerment of women has a positive effect on their influence on decisions in the household in Lao PDR (CARE, 2016). As women use their earnings more often to purchase food or to cover the needs of their children (FAO, 2017), increasing the capacity for women to exercise agency in domains where, hitherto, they had been excluded from can have positive effects on food security.

A potential intervention includes the following two activities: (1) Dissemination of time-saving tools for women (e.g. rice mill, cart, cookstoves), (2) Inter-gender negotiating trainings for both men and women.

6. Demand driven extension to facilitate market participation (Cause of Food Insecurity to be addressed: Improve income, through increased market engagement or adoption of new technologies)

Lao agriculture is simultaneously characterized by relatively low use of technical inputs (e.g. fertilizer, vaccines, …) and the rapid expansion of new crops, followed in some cases by their demise. These contradictory images reflect both farmer's willingness to experiment with new opportunities and the existing scope for improvement in the provision of services (including technical information as well as opportunities to engage in commercial agriculture). There is, in parallel, and less well documented, a perception that traditional approaches to the provision of these services, that rely on existent knowledge and capacity at local level, are insufficiently flexible/responsive to the new economic environment in which agricultural households make their decisions. We suggested an intervention that shifts the emphasis of extension to the farmer as a client, through the provision of grants that can be used solely for the acquisition of extension trainings to be provided at local level.

Given resource constraints, it was clear that it was not feasible to pilot and evaluate interventions addressing all six themes/constraints. The final selection made use of two types of information: an ex-ante evaluation of these pilot interventions (essentially building on information available to the research team) and comments from different stakeholders, who were invited to discuss these different possibilities in a public workshop.

The ex-ante impact assessment framework described in Figure 3 was converted into a matrix with six categories, which is reported in Table 8. Each potential intervention was classified on a 3-level scale (1 = high/desirable, 0.5 = neutral, and 0 = low/not desirable) with a final score reflecting the unweighted average of all six criteria. The matrix does not include the indicators *Need for the intervention* and *Potential impact* as the participants in the workshop and the steering committee meeting confirmed both for all potential interventions.

The first column in Table 8 shows the number of all households that are potential beneficiaries from the intervention, building on information collected during the first phase of the project (either secondary information, such as LECS or the Agricultural Census, or primary data, collected as part of this project). The evaluation of the need for new research reflects our own review of published literature and project reports (emphasizing research either in Lao PDR, summarised in the Evidence Gap Map, described above, or in neighbouring countries). Again, the scarcity of evidence that supports this analysis is evident: only in the case of the intervention on women's empowerment was there rigorous research already available. The feasibility category reflects if there are potential project partners in Lao PDR (reported in parenthesis), who expressed their willingness to collaborate in any future work.

As Financial Indicators, we considered two dimensions. First, we ranked the anticipated cost of an intervention (with higher scores given to lower cost). Second, we also ranked the interventions according to their ex-ante Benefit-Cost Ratio (BCR).

The fifth indicator, which is time to impact, reflects whether an intervention was expected to have an immediate influence on the food security of households in the northern uplands or the expected time to impact. Finally, the sustainability criteria reviews the importance of constraints to scaling-up the proposed work, if proven worthy. There were only concerns for the insurance intervention, with uncertainties about policies and regulations, as well as the self-control intervention, with potential ethical concerns.

As a result of this exercise, rodent control emerged as the highest ranked potential intervention, with improving self-control and promoting demand driven extension on a shared second place. There were serious concerns about the feasibility of piloting any work on index insurance, given the lack of knowledge on the relation between potential indexes and shocks/losses which led us to disregard its feasibility within the timeframe of this project – although it simultaneously highlighted the need to build the evidence on which any future work could build upon. As a result, five possible interventions were put to discussion in a public workshop.

The goal of the workshop was to obtain feedback on the proposed pilot interventions, including suggestions regarding which ones to prioritize. It took place at Settha Palace Hotel, Vientiane capital, Lao PDR on the 12th May 2017. One of the main objectives of the workshop was to consult with the participants on the proposed interventions from the project to improve food security. There were 44 participants from different organizations to attend this meeting. The represented organizations were: PAFO and Provincial Industry and Commerce of Luang Prabang and Xiengkhouang, Department of Planning and Cooperation (MAF), Department of Livestock and Fishery (MAF), Department of Crops (MAF), DAEC, NAFRI, CARE International, ERIIT, CIAT, NUDP, FAO, GIZ, EU, WFP, Lao Women Union, Department of Domestic Trade (MoIC), Oxfam, Helvetas, IRD, RASO, NIOPH, Policy Research Center (NAFRI) and the head of the cattle group from Thoulakom District, Vientiane Province. A substantial part of the workshop was devoted to group work of the participants to discuss the potential pilot interventions. After a presentation of the possible interventions, the participants were divided into 5 groups and each group took responsibility for one intervention and asked to conduct a SWOT analysis of each intervention, which was then discussed publicly.

Table 8 Ex-ante Impact Assessment for six food security interventions

Intervention	**(1) Potential beneficiaries**	**(2) Need for Research**	**(3) Feasibility**	**(4) Financial Indicators**		**(5) Time to impact**	**(6) Sustainability**	**Final Score**
indicator	**No. of households**	**Research available**	**Potential cooperation partners?**	**Total cost, in US$ (intervention / IE)**	**BCR**	**Years**	**Scalable**	
Rodent control	114,735[a] *(1)*	Some *(0.5)*	No *(0)*	18,497 / 70,241 *(1)*	4.90 *(1)*	Immediate *(1)*	Yes *(1)*	*0.79*
Market reform	50,638[b] *(0)*	Some *(0.5)*	Yes (ADB) *(1)*	31,867 / 45,293 *(0.5)*	2.00 *(0.5)*	1-2 years *(0.5)*	Yes *(1)*	*0.57*
Index insurance	133,258[c] *(1)*	Some *(0.5)*	No *(0)*	82,050 / 56,779 *(0)*	0.96 *(0)*	1-2 years *(0.5)*	*No* *(0)*	*0.28*
Self-control	39,152[d] *(0)*	None *(1)*	Yes (GIZ) *(1)*	7,392 / 30,366 *(1)*	1.80 *(0.5)*	Immediate *(1)*	No *(0)*	*0.64*
Female empowerment	139,830[e] *(1)*	Yes *(0)*	Yes (CARE) *(1)*	34,639 / 42,795 *(0.5)*	0.67 *(0)*	1- 2 years (0.5)	Yes *(1)*	*0.57*
Demand led extension	133,258[c] *(1)*	Some *(0.5)*	Yes (ACIAR) *(1)*	52,531 / 44,770 *(0)*	3.62 *(1)*	1 years (0.5)	Yes *(1)*	*0.64*

Note: [a] Number of farming households with rodent affected rice storage in the northern uplands, [b] Number of households owning cattle in the northern uplands, [c] Number of farming households in the northern uplands, [d] Number of household with low self-control in the northern uplands, [e] Number of households in the northern uplands

Reflecting this process and the two sources of information that we brought together, we shortened the list of potential work to: 1) rodent control (later split into different approaches, reflecting differences between wet and dry seasons in terms of awareness of the problem and cost-effective ways to address it), 2) demand-led extension and 3) analysis of feasibility of index insurance. Before we present the methodology used to progress our work, we present a brief summary of each line of work.

7.2.1 Summary description of selected pilot interventions

1. Promoting a rodent contest to reduce post-harvest losses during the dry season

Smallholder farmers in the northern uplands are known to suffer large damages to stored rice due to rodents. Recent estimates suggest that, every year, smallholder farmers lose 12% of the rice production to rodents before harvest (Brown and Khampoukeo 2010) and additionally 11.7% of rice in their storages (Brown et al. 2013). The majority of farmers consider rodents as the most important challenge for upland rice production in Lao PDR (Brown and Khamphoukeo, 2007). Given the scale of this problem, some research has investigated ways to control rodent pests, in Lao PDR and South East Asia (see the reviews of Singleton (2003) and John (2014)). John (2014) concluded that coordinated action of farmers in a village is a key component for successfully managing rodent pests, making cooperation one of the main challenges to rodent control.

Most farmers who practice rodent control in the northern uplands of Lao PDR, do it individually and in the rice fields during the wet season (Brown and Khamphoukeo, 2007). However, the movement and reproduction rates of the main pest rodent, the black rat (*Rattus rattus*), makes it necessary to collectively and continuously practice rodent control in both habitats to reduce the rodent population sustainably (Brown and Khamphoukeo, 2010; and Jäkel et al., 2016).

In this pilot, we promoted a decentralized approach that aims at involving substantial numbers of households in the control of rodents throughout the dry season. This will be achieved through the organization of a competition that awards prizes to the farmers who cull most rodents in the dry season. The prize will be an incentive for farmers to participate in rodent control while the definition of a specific time for the prize is expected to induce farmers to coordinate their actions. In addition, we also plan to evaluate the relative effectiveness of different prize schemes, in particular through a comparison between cash prizes and merit awards.

2. Training cooperation to reduce rodent damage in the field during the wet season

As mentioned earlier, collective action of farmers in a village is the key to successful rodent management. The aim of this intervention is to motivate cooperation in rodent control during rice production by inviting farmers to play a common pool resource game, framed as a rodent control game, at the beginning of the wet season. Participants in the game can potentially learn two things: the benefits of cooperation and their peers' willingness to cooperate in rodent control. After playing the game, farmers are expected to contribute a higher amount of time to rodent control in the real world. Previous uses of a similar strategy in a developing country context include Meinzen-Dick et al. (2016), who used economic games to change behaviour and preferences, and to promote collective action of smallholder farmers.

The implementation of the game is combined with the promotion of Ecologically-Based Rodent Management (EBRM) in the villages. EBRM is a well-tested approach to sustainably reduce the rodent population in a village setting (also in the northern uplands of Lao PDR) (see Singleton, 2003; Brown and Kamphoukeo, 2010; Jäkel et al., 2016). As earlier trials showed that communal rodent hunting is the cost-effective activity in the area, the pilot promoted it at the village level together with trainings on EBRM, in all villages. DAFO staff help farmers in setting

up and implementing the community activities. Hence, our pilot measures the effect of improved coordination once information constraints on existing best practices are alleviated.

3. Demand Led Extension

In a demand-led extension approach, recipients - as part of a community – request extension trainings according to their needs. Similar to community driven developments for the provision of public goods, this approach is motivated by the benefits of decentralized decision making which include communities' better knowledge of their needs as well as their better position to supervise the implementation of the trainings.

The central mechanism of change proposed in this intervention is the definition of grants, to be administered by households at village level. These grants are exclusively to pay for the acquisition of advisory services for rural development (broader focus beyond technology diffusion including marketing and other domains, e.g. nutrition). The need and nature of these services is to be determined by farmers themselves. The intervention acts as a clearing house by collecting requests for services (rankings of problems and characteristics of delivery of potential solutions) and expressions of interests of potential suppliers of advice and facilitating the matching process.

4. Studying the feasibility of index insurance against weather shocks

Index insurance is the natural approach to address the identified importance of covariate shocks (that cannot be insured at local level) in a context of pervasive informational asymmetries and high transaction costs (that prevent the development of multi-peril insurance based on verified losses). However, given the lack of background information about production and the distribution of shocks (needed to develop the statistical basis of the insurance product) and the limited duration of the project, it was clear from the start that it would not be possible to develop and evaluate any pilot insurance product.

As a result, the research activities were limited to advance the definition of what index insurance can look like in the agroecological conditions of northern Lao PDR, and in particular the feasibility of reducing basis risk, which the literature identifies as one of the major limitations to the adoption of such products.

7.3 Rodent Control

7.3.1 Importance of the problem

Every year rodents destroy significant amounts of rice, both before and after harvest (Brown and Khampoukeo 2010; Brown et al. 2013). Increasing extreme weather events and agricultural intensification might further increase the threat of this pest in the coming years (John, 2014). As a result, rodents are and will remain one of the main threats to smallholder farmers' food security in northern Lao PDR (and, likely, in other areas of Southeast Asia).

In northern Lao PDR, the main pest rodent is the black rat (*Rattus rattus*). Farmers have the tools and skills to cull black rats, and the persistence of the problem reflects the biology of the species, in particular its reproduction rate: black rats become sexually mature after 3 to 4 months, and female black rats can have a litter every two months each with up to 10 pubs (Khamphoukeo et al., 2003), which is only constrained by access to food (Gillespie, 2004).

Although much attention is placed on losses in the field (pre-harvest), black rats move to the villages after the harvest to feed on the stored food of the villagers. Douangboupha et al. (2009) reported highest pregnancy rates in the village habitat during the dry season, where 85% of the

female rats were pregnant. The effectiveness of rodent control is further reduced by the fact that black rats forage for food within an area of up to 100m from their burrows.

As a result of both this high reproduction rate and the spatially limited impact of control activities, control of this pest requires the simultaneous participation of a large number of farmers: in its absence, the efforts of each individual farmer are soon proved worthless. Such coordination is, however, difficult to achieve given the fact that farmers benefit from their neighbours' efforts in reducing pest pressure creates the basis of a social dilemma: each farmer has the incentive to let others spend effort in controlling rodents while allocating his own time and resources to activities that exclusively benefit them. As a result, overcoming the free-rider problem is the main challenge to sustainably control rodents as has been recognised in the Ecologically-Based Rodent Management (EBRM) literature (John 2014, Brown and Khamphoukeo, 2010; Jäkel et al., 2016).

EBRM is a rodent management approach which was developed, in large part with ACIAR funding, on the basis of scientific findings in areas of pest rodents' biology, behaviour and habitats (see Singleton et al. (1999) for a summary). From this knowledge a set of practices were derived, which include sustainable rodent culling approaches, but also the protection of storage facilities and village hygiene. In particular, recommended practices are expected not to have negative environmental externalities (as rodenticides do). This approach has proven to be successful to reduce the pest pressure by rodents in northern Lao PDR (see Singleton, 2003; Brown and Khamphoukeo, 2010; Jakel et al., 2016), but relies on coordinated activities at a village level (John, 2014).

To evaluate the effects of any rodent control activity, we initially worked in 36 villages (later increased to 52 villages), randomly selected from a list of villages in the districts of Viengkham and Pakxeng, in Luang Prabang province. This work was not implemented in Xieng Khuang as local authorities did not consider this problem to be important. In each village, 12 households were randomly selected from the village roster to be part of the evaluation.

Table 9 summarises the problem in our sample of villages. When compared with estimates of damage in the literature, farmers seem to underestimate its importance during the dry season (post-harvest, when rice is kept in storage) and over-estimate it during the wet season (when losses are easily observable in the field). They also seem to be more aware of spillovers between neighbours during the wet season. Unsurprisingly, 80.3% of households then put more time and effort into rodent control in the wet season, although only individual control (mostly traps) seems to be used. Only 34% of the households are aware that the rodents that cause damage in the field also move from the village to the field after the dry season.

Due to the large differences in how the problem is perceived in each season, we designed and evaluated different ways to promote coordinated rodent control: training cooperation in the wet season and the use of incentives (monetary prizes and awards) in the dry season.

Table 9: Damage, rodent control and perception of the importance of the problem

	Wet Season			Dry Season		
	N	Mean	SD	N	Mean	SD
Damage by rodents (in kg)	432	383.2	352.1	432	53.24	50.09
Active in rodent control	432	0.870	0.336	432	0.845	0.362
Use traps	432	0.863	0.344	432	0.831	0.375
Do hunting	432	0.051	0.220	432	0.035	0.183
Others' strongly benefit from own rodent control	432	0.470	0.500	432	0.333	0.472

7.3.2 Using contests to promote coordinated control of rodents

We piloted a contest that offered prizes to the villagers who culled most rodents during the dry season (ending at the time of Lao New Year). The contest was deliberately designed to be simple, requiring no specific organizational skills and with monitoring and enforcement of the rules delegated to villagers themselves. It was hoped that this simplicity would make it potentially scalable, if proved effective. The pre-defined and limited duration of the contest aims to encourage farmers to use their time to act simultaneously. The contest was initiated through a village meeting where the rules were explained, and prizes were handed in a public meeting at the end of the contest.

The contest was organized in two rounds, implemented during the dry seasons of 2017 and 2018, with a different prize structure offered in each round. In the first round, held between December 2017 and April 2018, we tested the effects of both merit and monetary prizes.

The merit prize was defined as a certificate issued and handed over by a DAFO representative. The motivation for this purely symbolic prize is to understand how important extrinsic motivation to contribute to the common good may be in addressing problems such as rodent pest pressure. It also has an immediate policy effect: given its very low (or zero) cost, this type of prizes is frequently suggested and offered as being enough to motivate farmers to adopt innovations, promote conservation, repair infrastructure, etc.

In order to understand how different monetary prizes influence participation in the contest, we trialled three monetary prizes: 250,000 LAK, 500,000 LAK or 750,000 LAK. In addition to the prizes for the winner, each participating household who culled more than 100 rats during the contest was eligible for a prize of 100,000LAK to be allocated through a lottery (offered in villages with a monetary prize only). The objective of this lottery was to encourage participants to keep participating in the contest even if it became apparent that they would not be the winner of the competition – an aspect that, as we will see, shapes the effectiveness of this approach.

Villages were randomly allocated to one of four categories, of equal size (9 villages): merit prize, monetary prize (3 villages to each prize) and both monetary and merit prizes (3 villages to each value of the monetary prize). The remaining 9 villages were allocated to a control group, where no rodent control activity was implemented by the project.

A qualitative study reviewing the implementation of the contest revealed that the lottery was confusing for participants and interviewed households suggested that instead of offering one single prize, a contest with multiple prizes (for the three most effective participants) would potentially attract more attention and encourage the participation of more households. This change was implemented in the second round of the contest, held between January and April 2019, during which only one prize scheme was used in the 27 villages that had been allocated to any of the prizes in the first round. Due to the large participation (and, ultimately, effect) of the 500,000LAK prize trialled first, the redesigned prizes offered this amount to the person who culled most rodents, with additional prizes offered to the second and third most effective participant (valued at 250,000 LAK and 150,000 LAK, respectively). Because it was likely that a comparison between 27 treated villages and 9 control villages might reduce the power to detect an effect, we randomly selected an additional 16 villages (where no work had been conducted so far), leading to a control group of 25 villages (and a total of 52 villages).

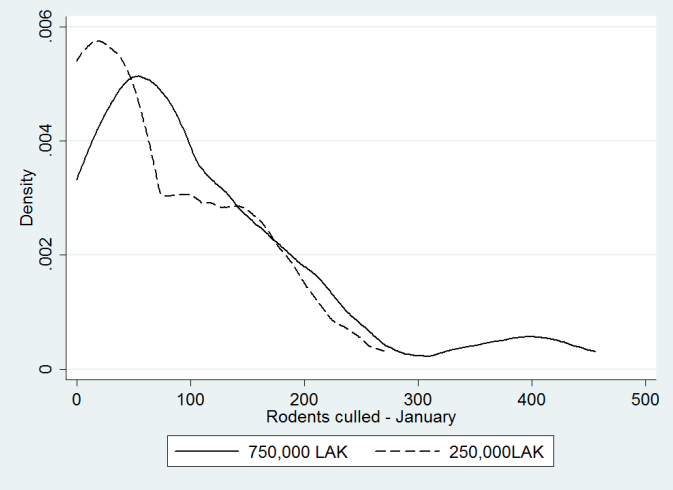
The tests of the integrity of the design (Section 5.3.2) confirm that, in both rounds, the randomization was successful in achieving balance for the variables that are likely to matter most for individual behaviour in the contest and for postharvest losses. This conclusion is reinforced by an F-test of the joint significance of these variables in explaining treatment status. In the first round, with the larger number of treatment groups, there are some meaningful

differences that are, in general, relatively minor and would, if anything, bias our estimates downward. Additionally, we test the importance of selective attrition. In all cases, treatment status is not correlated with the probability of attrition.

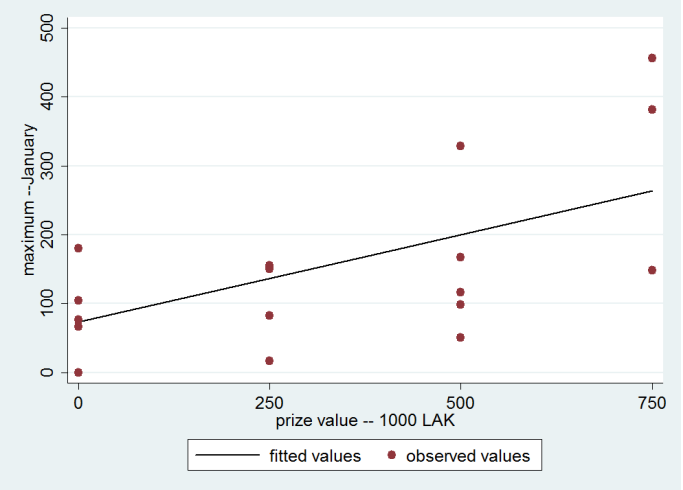
In addition to the household data we also have monitoring data on the number of participants and the number of culled rodents throughout the duration of the contest. In the first round of the contest, on average 10 households per village (or 14% of the village number of households) participated in the contests. Participation was higher in villages with monetary prizes (16% and 17% of the households in villages with only monetary prize and both monetary and merit prizes, respectively) than in villages where only the merit prize was offered (9% of the village). The largest number of participants was registered where the prize was set at 500,000 LAK (participation rate: 21% of the households). Participation was slightly lower in the second round: on average, 9 households per village (approximately 12% of the households in a village) participated in the contest.

Focusing on effort (number of rodents culled per participant), there are noticeable differences across the different prize categories. Effort is clearly lower in those villages where only the merit award was offered, and increases with the value of the prize.

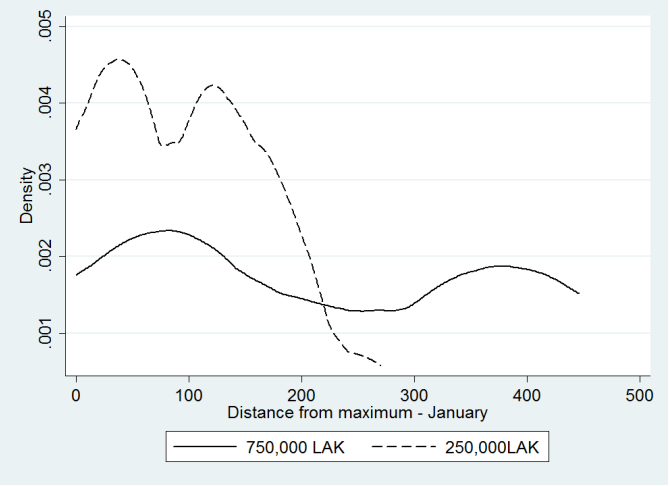
This data allow us to discuss two other aspects that may matter to explain the impact of this contest: the timing of the culling (earlier reductions in pest pressure should lead to higher reductions in losses) and the concentration of effort (concentration of culling effort in a small number of participants should lead to smaller reductions in losses, given the limited spatial impact of rodent control). The effect of the different monetary prizes on these variables can be summarised in Figure 7. We present only the results for the lowest (250,000 LAK) and highest (750,000 LAK) monetary prizes, given that behaviour in the intermediate prize is somewhat in between of these two.



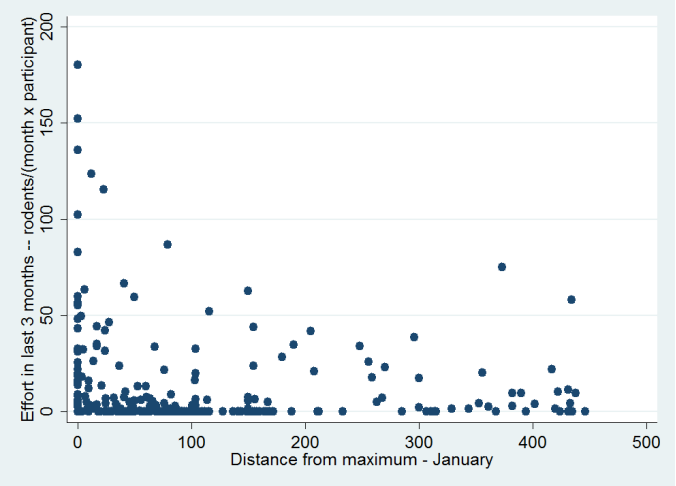
(a) Effort, month 1: 250,000 LAK vs 750,000 LAK



(b) Maximum (month 1) per value of prize



(c) Distance to maximum: 250,000 LAK vs 750,000 LAK



(d) Effort in last 3 months vs distance to maximum

Figure 7: The potential discouraging effects of higher prizes

The first thing to notice is that higher prizes lead to higher effort in the first month of the competition, both in terms of the overall number of culled rodents (Figure 7a) and in terms of maximum number of culled rodents in each village (Figure 7b). Given the distribution of effort in the first month of the competition, a much larger number of initial participants performed much worse than the initial best performer in villages that were offered the largest prize of 750,000LAK (Figure 7c). This distance is associated with both the probability of dropping out of the contest after the first month and the effort in the remaining of the competition (Figure 7d). Overall, this data suggests that the relation between the value of the prize and sustained participation and effort in the contest throughout its duration (both of which would lead to larger reductions in storage losses) is ambiguous: higher prizes may not lead to larger reductions in

losses if they discourage sustained culling of rodents by those participants who may consider that their chances of winning are exceedingly low.

We estimate the impact of this intervention using a difference-in-differences specification of equation 6 (section 5.3.2). Results for round 1 (2018) are presented in Table 10. The main variable of interest is damage to stored rice and the coefficient of interest is the interaction between treatment and round (an indicator variable that takes value one if data was collected after the end of the contest). We estimate the effect of both types of prizes (money, merit) and their possible interaction (both defined as dichotomous variables that take the value of 1 if the household is in a village where this prize is offered, either alone or together with monetary awards), while the possibility of an interaction between the two types of incentives is captured by the coefficient on the variable (Merit + Money) X round (an indicator variable that takes the value of 1 if the household is in a village where both types of prizes are offered). The conclusions are relatively straightforward: merit awards do not lead to noticeable reductions in losses in stored rice while monetary awards do (-15.5kg per household, approximately 25% of the losses in the control group). There are no clearly identifiable gains from combining the two types of awards.

The second column presents the same analysis when we consider the effect of different values of the monetary prize. The effect of monetary prizes on damage to rice stored is driven solely by the intermediate valued prize (500,000 LAK), with neither lower nor higher prizes capable of reducing damages significantly. This apparently counterintuitive result may be explained by the fact that effective rodent control requires continued effort (to address the reproductive behaviour of this pest), ideally spread through a large number of households (to address its limited geographical effect). Low prizes do not seem to motivate enough households to devote time to rodent control while, as shown previously, high prizes do not seem capable of sustaining initial efforts given that they seem to lead to higher rates of drop-out of the contest after the first month.

Table 11 presents similar results for the second round of the contest, and they are simpler to explain, as only one treatment group with monetary prizes are reported. We find similar reductions in the damage to stored rice: on average, a household exposed to the contest reported losses that were 14.6 kg less than a household in a control village, a reduction that is equivalent to 30% of the average damage in control villages.

Table 10: Evaluating the impact of contest (round 1): ITT estimates

Dependent variable:	Rodent damage to stored rice (in kg)	
merit X round	5.164	5.164
	(8.043)	(8.088)
	[0.560]	[0.554]
money X round	-15.51*	
	(8.338)	
	[0.092]	
250,000 LAK X round		-15.79
		(10.77)
		[0.235]
500,000 LAK X round		-26.69***
		(9.738)
		[0.040]
750,000 LAK X round		-4.700
		(9.155)
		[0.668]
merit + money X round	4.876	
	(11.75)	
	[0.698]	
250,000 LAK + merit X round		11.91
		(20.06)
		[0.634]
500,000 LAK + merit X round		11.40
		(12.75)
		[0.437]
750,000 LAK + merit X round		-7.723
		(14.61)
		[0.673]
Observations	730	730
R-squared	0.030	0.063

Note: Standard errors clustered at village level in parentheses. Wild bootstrapped p-values within brackets. *** p<0.01, ** p<0.05, * p<0.1

Table 11: Evaluating the impact of contest (round 2): ITT estimates

	Rodent Damage to stored rice (in kg)
Treatment	-14.61***
SE	(5.445)
Wild-BS	[0.009]
Observations	1,034
Number of households	517
R-squared	0.057
Control mean	46.094

Note: Standard errors clustered at village level in parentheses. Wild bootstrapped p-values within brackets. *** p<0.01, ** p<0.05, * p<0.1

The prizes we trialled can be interpreted as a payment for the positive externalities generated by individuals who devote effort to reducing pest pressure in a village. Quantifying those externalities is important to understand who benefits from this type of program, and in particular if neighbours of participants benefit from it (even when they don't participate). Given that households self-selected into the contest, we use propensity score matching to estimate spillover effects (see section 5.3.6).

Table 12 reports the estimates of these spillover effects The first two columns present the reduced damage for participants and non-participants. The former effect is substantially larger but imprecisely estimated, reflecting the reduction in the estimation sample. In columns (3) and (4) we take advantage of the fact that black rats do not forage beyond 100m from their burrows, to split the group of non-participants in households with and without a neighbour participating in the contest within that distance (ie, <100m distance of residence). Non-participants who live close to contest participants report a reduction in damage that is identical to participants themselves, demonstrating the importance of spillovers in this process. Other non-participants do not benefit from the contest.

Table 12: Spillover effects of the rodent contest

	(1)	(2)	(3)	(4)
Matching method	Kernel	Kernel	Kernel	Kernel
Variables	Participants	Non-participants (all)	Non-participants (w/ no participating neighbours)	Non-participants (w/ participating neighbours)
Money X round	-24.18	-16.35	-8.011	-23.89**
	(19.39)	(10.12)	(12.36)	(10.22)
Merit + money X round	16.86	7.711	-3.705	20.27
	(22.16)	(8.692)	(10.77)	(12.92)
Households – control villages	83	83	83	83
Household – treatment villages	31	157	87	70
R^2	0.057	0.031	0.036	0.042

Given the size of these direct and indirect effects, we are also interested in analysing the effect of the contest on the village economy. In particular, we are interested in any market effect that may occur before the next harvest, when stored rice from the previous harvest is coming to an end or has been totally consumed. Reduced damage due to the contest can lower the demand of net buyers and increase supply for net suppliers on the local rice market in the villages. This change in the demand and supply scheme and, correspondingly, on local prices, may be especially pronounced in villages without direct road access during the wet season, where most of the supply of rice is local surplus. In these villages, it is perhaps possible to expect a reduction in the rice price due to the savings (reduced damage) caused by the contest.

In a separate price survey with local millers, we collected rice price data for each village. The data was collected for a period between January 2017 and December 2018, and in the analysis, we focus on the effect of monetary prizes (both groups where a monetary prize was offered) on the rice prices in remote villages (18 villages have no road access in the wet season, 14 of which in the treatment group). The general equilibrium effects within villages without road access during the wet season are estimated using the following equation:

$$(13) \quad P_{t,2018} = \alpha + \beta_1 P_{t,2017} + \beta_2 \text{Money} + \beta_3 \text{Merit+Money} + \theta X + \varepsilon$$

where P stands for the prize in month t (Jan to Dec) in 2017 or 2018, X are variables controlling for productive capacity (upland rice area, land planning restrictions) as well as the capacity to manage rice shortage in the wet season (rice bank). The estimated coefficients of interest (β_2) for all months of the year are reported in Figure 8: between June and September (ie, when previous rice harvest is close to exhausted and before the new one), households in treatment villages benefited from significantly lower rice prices.

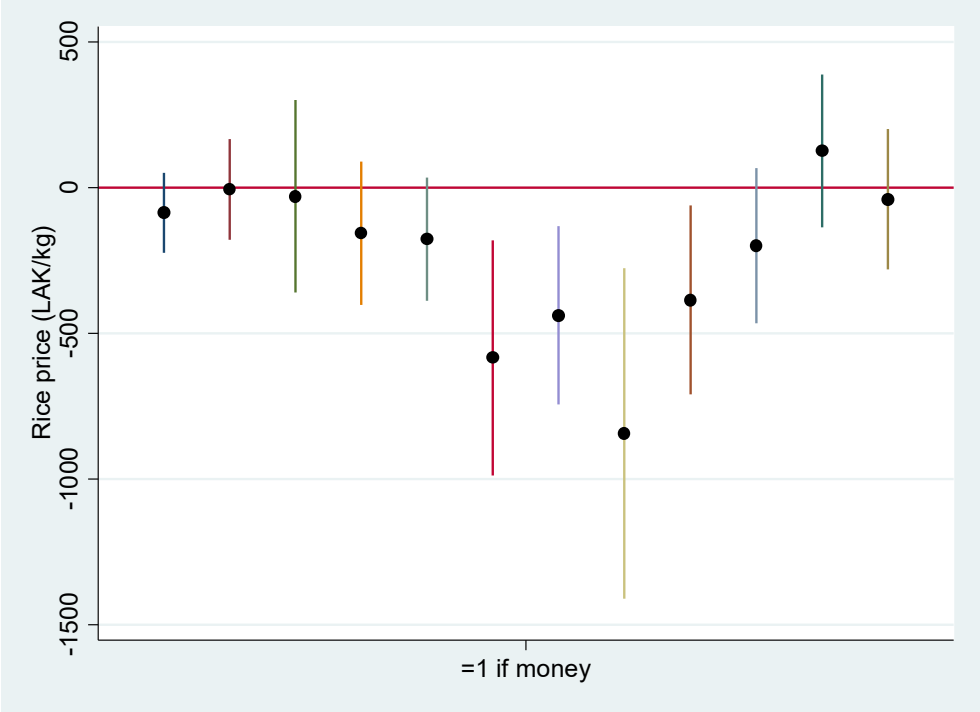


Figure 8: Treatment effects of monetary prizes in remote villages for each month from January to December (the lines indicate 95% CI). The wet season in the region lasts from May to October (rice harvest in October/November).

Pooling together all the data for the wet season (between May and October), we can estimate an overall price effect, using the following model:

(14) $P_{t,2018} = \alpha + \beta_1 P_{t,2017} + \beta_2 \text{Money} + \beta_3 \text{Merit+Money} + \beta_4 \text{Isolated} + \beta_5 \text{Money} * \text{Isolated} + \beta_3 \text{Merit+Money} * \text{Isolated} + \theta X + \varepsilon$

The results of this regression are reported in Table 13. The coefficient for the interaction of monetary prize and remoteness is significantly negative, which indicates a reduced price in remote villages. In the second model specification, we find on average 500 LAK/kg lower prices, which is equivalent to a 20% reduction of the prices.

Table 13: Price effects of the contests

	(1)	(2)	(3)
Variable	Rice price (LAK/kg)		
price (2017)	0.964***	0.985***	0.816***
	(0.0476)	(0.0445)	(0.0806)
money	32.26	72.14	34.17
	(43.38)	(46.15)	(53.35)
merit & money	-72.86	-84.34	9.465
	(114.9)	(115.9)	(144.5)
isolated	134.7	486.6***	362.8***
	(87.03)	(82.76)	(101.5)
money X isolated	-151.1	-471.3***	-348.7***
	(104.2)	(86.94)	(105.9)
merit & money x isolated	206.7	169.5	118.2
	(130.6)	(126.9)	(162.0)
Upland		14.4	6.182
		(45.79)	(51.99)
Land and Forest Allocation		-325.9***	-260.6***
		(49.96)	(64.13)
Rice bank		51.86	53.22
		(32.25)	(46.70)
constant	87.82	262.2**	754.9***
	(129.8)	(108.7)	(194.9)
Month FE	no	no	yes
Observations	189	189	189
Number of villages	27	27	27

7.3.3 Training cooperation

As seen in Section 7.3.1, households in this region are acutely aware of the extent of rodent damage in the plot during the rainy season. As a result of this awareness, there is perhaps a less clear need for an external incentive to encourage them to participate in rodent control activities. That said, cooperation is perhaps more needed than during the dry season, as Jakel et al.(2016) showed that collective rodent hunting is the most cost-effective EBRM practice in the northern uplands. Building on these findings, the aim of this pilot was to promote cooperation within villages.

We build on a small literature that explores the possibility of using economic games as pedagogical tools in the field and develop a game that is framed as a rodent control problem: farmers (as players in the game) have to decide whether to allocate their effort (time) to either a private good (their own rice harvest) or a public good (rodent pest pressure), knowing that the payoff (symbolising their harvest, and paid in real money at the end of the game) depends on the group decision as whole (ie, how much time the set of players devote to rodent control). The payoff matrix, distributed and discussed with all participants at the start of the game, formalises this decision. Participants in the game were asked to imagine that other participants were farmers with plots neighbouring their own plots. In total seven rounds of the game where played, and the participants were asked to think of every round as one production season.

An indicator variable for playing this game is our treatment variable. The game was played in 18 randomly selected villages (and, as such, its impact is independent of the dry season activities conducted in these villages), at the start of the rainy season (ie, right before rice is planted, and once the contest described in Section 7.3.2 was concluded), by five groups of five players from different households in each village. Members of households who were interviewed at the baseline were invited first (maximum 12 per village, but usually less due to attrition) with the remaining participants being randomly selected from the village roster. In total 450 households played the game (of which 175 were from previously interviewed households).

Participants made their decision regarding how to distribute their time individually, as communication was not allowed during the game. At the end of each round, the total amount of time allocated to rodent control was announced, allowing individual players to understand how cooperatively other players were playing and calculate their individual payoff from that round. The payoffs were aggregated over a session (seven rounds), at the end of which every player was individually informed about her/his total payoff. Every participant received a payment after the game that reflected his/her performance as well as the performance of the group.

After completing the game, participants were given the opportunity to talk for five minutes and reflect about the game and how it can be played to increase their payoff. After this discussion, they were allowed to decide (via secret vote) whether they would want to play a second session of the game, knowing that only one of the (randomly selected) sessions would be paid at the end. Approximately half of the groups decided to play a second session. Table 14 summarizes the time used for rodent management and payoffs for the different types of players and games.

Table 14: Time used for rodent management (RM) and total payoff

	Session 1	Session 2
A: all players (N=450)		
Time used for RM	2.489	2.216
	(1.238)	(1.050)
Total payoff (in 1,000 LAK)	51.162	51.724
	(5.948)	(4.489)
B: disaggregated by previous participation in study		
Participants (N=175)		
Time used for RM	2.421	2.196
	(0.099)	(0.101)
Total payoff (in 1,000 LAK)	51.480	52.030
	(0.481)	(0.485)
Non-participants (N=275)		
Time used for RM	2.531	2.293
	(0.071)	(0.941)
Total payoff (in 1,000 LAK)	50.96	51.51
	(0.342)	(0.372)

In addition to the game, and in collaboration with extension officers of Viengkham DAFO, we organized a training on collective rodent control activities and demonstrated how to organise a communal rodent hunting in all 36 villages. Villagers were then encouraged to organize their own rodent control activities, without further involvement from the project. As a result, the analysis we present should be understood as the causal effect of playing the game once information constraints about how to implement collective activities are alleviated (although

these cannot be driving any of the results, as they were implemented in both treatment and control villages).

The balance tests (individual t-tests of the main variables) show that there are only significant differences between households in treated and control villages in two variables (asset index, and whether the main rice plot borders other plots). An F-test of the joint effect of all variables on treatment status confirms the success of randomization (p-value=0.206). Attrition in subsequent survey rounds is also uncorrelated with treatment status, and non-compliance (being invited to the game but deciding not to participate) was quite small (9.3% of the households) and we cannot find any differences between compliers and non-compliers (p-value of F-test: 0.159).

We use an ANCOVA specification to estimate the treatment effects of this intervention. In Table 15, we report both the Intent-To-Treat (ITT) (ie, living in a village where the game was played) as well as the Local Average Treatment Effect (LATE) (ie, the effect of participating in the game). We report two values for each estimate (uncontrolled and when we control for unbalanced variables at baseline -- i.e., assets and whether main rice plot neighbours other plots). We focus on all outcomes in the pathway from playing the game to damage in rice plots (our main outcome of interest).

Focusing on the ITT estimates with controls, playing the game increased the participation in collective rodent control activities (EBRM training, and collective rodent hunting by the project and the village) by 9%, 10% and 13%, respectively. These changes translate to a reduction in the area of rice damaged by rodents of around 4.2pp (or a relative reduction of approximately 22% of the damage in control villages).

The ITT results allow us to calculate the benefits of the treatment in the quantity of rice or monetary terms. Given that, in control villages, households harvest on average 1780kg of unmilled rice, the reduction in damage is equivalent to an additional harvest of 92.1kg of unmilled rice (or 63.3kg of milled rice), which corresponds to the quantity of rice consumed by an average family in ~2 weeks. On average, the price of milled rice was 5,840 LAK/kg and 5,080 LAK/kg in September 2018 (before harvest) and December 2018 (after harvest), respectively. These prices allow us to calculate a benefit per capita of 321,000LAK to 370,000LAK from the intervention. Considering the cost of the intervention per village of 1.77.million LAK (Game: 1.48 million LAK; Training: 170,000 LAK; Hunting: 120,000 LAK), we can calculate a benefit-cost ration of 12.1 and 14 for this intervention.

The LATE estimates are larger and more precisely estimated. The reduction in damage in rice plot for participants in the game is slightly larger (5.1pp), and translates to a reduced damage of 111.9kg unmilled rice (or 76.9kg of milled rice). The value of these savings can be estimated to be between 391,000LAK and 450,000LAK.

We also quantify the effect of playing the game on time used in (general) community activities. In no case do we find a significant effect, suggesting that an increase in cooperation in rodent control does not increase cooperation in other domains. The negative sign of the estimates could in fact suggest some substitution, with households reallocating time away from other collective activities and into collective rodent control.

Table 15: Effect of playing the CPR game on main outcome variables: ITT and LATE estimates

	Participation in EBRM training	Participation in hunting (project)	Participation in hunting (village)	Damaged rice by rodents	Time participated in community activities
ITT estimates					
No covariates					
ITT	0.088	0.095*	0.098	-3.753**	-0.032
SE	(0.063)	(0.050)	(0.069)	(1.713)	(0.670)
Wild-BS	[0.181]	[0.072]	[0.174]	[0.038]	[0.938]
With covariates					
ITT	0.094*	0.105**	0.126**	-4.192**	-0.001
SE	(0.048)	(0.039)	(0.058)	(1.796)	(0.622)
Wild-BS	[0.090]	[0.019]	[0.067]	[0.043]	[0.998]
LATE estimates					
No covariates					
ATE	0.108	0.116**	0.119	-4.606**	-0.035
SE	(0.075)	(0.059)	(0.083)	(2.054)	(0.725)
Wild-BS	[0.176]	[0.062]	[0.173]	[0.034]	[0.962]
With covariates					
ATE	0.114**	0.127***	0.152**	-5.105**	-0.001
SE	(0.056)	(0.045)	(0.068)	(2.131)	(0.657)
Wild-BS	[0.087]	[0.018]	[0.067]	[0.043]	[0.991]
Control mean	0.662	0.508	0.344	18.772	5.831
N	399	399	399	333	336

There are at least two potential explanations (mechanisms) for how playing the game leads to changes in behaviour: players can learn about the benefits of cooperation (the explanation emphasised in much of the literature) or they can learn about others' willingness to cooperate. Although most of the farmers were aware of the existence of local spillovers between neighbours before the game (see the evidence in Section 7.3.1) it is possible that they have learned about the benefit of a large participation in these activities (as, in fact, emphasised in subsequent training). We collected data on both explanations by asking players directly about what they learnt in the game in two separate questions, each addressing one mechanism. Players' responses reveal that around 30% learned about the benefits of a large participation in a village in rodent management and more than 50% of the respondents indicated that the willingness to cooperation of others exceeded their expectations.

We use the approach developed by Imai et al. (2011) to estimate the causal mediation effect of the two mentioned mechanisms of the game (as explained in Section 5.3.5). We find a small and positive ACME for the first mechanism (learning about the benefits of cooperation) and a positive and larger ACMEs for the second mechanism (learning about other willingness to cooperate) on those outcomes that measure participation in collective action, which suggests that the second mechanism is more important in explaining the effect of the game. We do not find a significant ACME in either case when explaining reduced damage in the field, which indicates that the damage was not mediated by learning in the game, rather it is a consequence of the increased collective activities. This result opens the possibility that other ways of modifying knowledge about others' willingness to cooperate may be equally effective in promoting

7.3.4 Financial sustainability

A possibility to make the rodent control activities sustainable and scalable is to households to contribute to their financing. In the last round of the household survey, we included a very simple contingent valuation study to elicit willingness to contribute to each of these activities (contest and rodent hunting) if they were organized and managed at the local level. However, we did not trial this approach, and as such we have no hard evidence to support the conclusions of this analysis.

The results for the rodent contest are presented in Table 16. The majority of respondents stated that they would be willing to contribute money to a contest that was locally organised and managed. In that same table, we present results of total contribution, obtained when individual contributions are extrapolated to the total village size. Recall that the total value of the prizes (in its most recent version) was 900,000LAK: in 65% of the villages, stated contributions would be larger than the total amount required to cover the cost of the contest.

Table 16: Willingness to pay for rodent contest – Individual and extrapolated to village level

	N	Mean	SD
Individual			
Contribute to contest (1/0)	560	0.871	(0.335)
Willingness to pay – money (1000 LAK)	560	18.87	(23.31)
Village contribution			
Willingness to pay – money (1000 LAK)	52	1494.6	(1190.8)

We also collected information about willingness to pay for rodent hunting in the village among respondents who were surveyed during the first year. Table 17 summarizes the responses. Nearly all households are willing to contribute to the funding of this activity. Respondents were willing to contribute around 18,500 LAK per household, which is sufficient to organize hunting in the villages. Almost all respondents mentioned that they would be willing to participate in such activities, with a relatively high frequency of participation (on average, 3.7 hunts out of a maximum of 5), and this intention increased with previous exposure to the activity (in treatment

villages, where playing the game led to higher previous participation in these activities -- see Table 18.

Table 17: Quantifying WTP for collective control activities in wet season

Variable	N	Mean	SD
Contribute to hunting (1/0)	384	0.872	0.334
WTP for hunting	384	18.47	21.41
Participate hunting	384	0.951	0.217
Participation number of times (max 5)	384	3.758	1.651

Table 18: WTP rodent control activities in wet season

	(1)	(2)	(3)	(4)
	Contribute to hunting	WTP for hunting	Participate hunting	Participation number of times
	(1/0)	(in 1000 LAK)	(1/0)	(max 5)
Treatment	0.0280	2.755	0.0504**	0.438**
	(0.0286)	(2.094)	(0.0239)	(0.173)
N	384	384	384	384
Control Mean	0.849	15.49	0.930	3.578

Note: Standard errors in parentheses; * p<.1, ** p<.05, *** p<.01

7.4 Demand Led Extension

The Demand Led Extension (DLE) pilot formalises a decentralised approach to extension. Its aim is to give farmers the possibility to decide about the topic, level and provider of the extension services. Unlike traditional extension approaches, where farmers are mostly seen as the recipients of the extension services, in this approach they are seen as decision makers and, in this role, they can respond and make changes when they are not satisfied with previous services. The main goals of this approach are to better match the training to the needs of the farmers as well as to, potentially, improve the quality of the training provided. The mechanism through which these aims would be achieved were the provision of a grant at a community level, to be used to fund extension services. As a result, this approach shares important similarities with the Community Driven Development approach and shares many of its assumptions and limitations (see Mansouri and Rao (2004), Casey (2018), Wong and Guggenheim (2018) for reviews).

Traditional extension services in developing countries are often solely publicly funded, top-down, largely overstaffed, bureaucratic and seen as highly inefficient (Rivera, Qamar and Crowder, 2001). Since the 2000s, there is an ongoing transformation of the extension systems with the goals to improve advisory services by simplifying their structure, better meeting the needs of farmers and reducing their costs. The main claims are to involve farmers in decision making, decentralize, involve non-governmental sources (e.g. private or NGOs) and increase

the market orientation of farmers (Blum et al. 2020). Potential concepts were developed more than 20 years ago and some of them were already successfully implemented in developing countries. However, implementation of a decentralised approach such as the one piloted here is rare and there is, in particular, a lack of rigorous impact evaluations of its functioning (Blum et al., 2020).

The DLE approach piloted here relies on the provision of training grants to the village community. Committees in the villages were responsible to manage the intervention at the village level. The size of each grant was 1.25 Million LAK (approximately 170 AU$ per village or a little bit less than 1.8 AU$ per beneficiary household) per round, and in total, each village received three rounds of the grants, disbursed over three subsequent seasons, between the wet season 2017/2018 and the wet season 2018/2019 (inclusive). The intervention was implemented in 36 randomly selected villages in two districts in each of the provinces Luang Prabang and Xiengkhuang, with an additional 35 randomly selected villages acting as control villages, where only official extension services were available.

In what follows we present first the structure of this intervention (Section 7.4.1), followed by the main results (Section 7.4.2). As expected, we find that the likelihood of receiving any training is larger in the treatment than the control villages. Similarly, the subjective importance of the trainings for the household livelihoods as well as the knowledge gains from training were larger in the villages receiving the grants. These improvements translate into greater adoption of technological innovations (with adoption rates that are 16% and 30% greater in the treatment villages, in the first and second year, respectively). In terms of non-economic impacts, conclusions are mixed: we identify a positive impact measured trust towards outsiders as well as political efficacy, but a negative impact on perceptions of social cohesion within village, seemingly driven by respondents disappointed by collective choices. Finally, we estimate positive impacts on food security status in the second year, suggesting a relatively short-term lag in the effect of this type of interventions and, possibly, the utility of longer-term evaluations of its impact.

We then focus on the impact of the main form of technical training selected in these villages: livestock health and management (Section 7.4.3). The DLE intervention led to improved livestock management practices, with significant increases in the production of fodder (one of the main constraints to the development of this value chain). Furthermore, we find that the adoption of vaccines increased by more than 30% in the second year. These improved practices lead to a reduction of the mortality rate in the second year, which translate into monetary benefits exceeding the total cost of this intervention by approximately 50%.

7.4.1 Structure of the intervention

The DLE intervention was structured in six steps, which are summarised in Figure 9.

As a first step, the approach and main structure was presented to the local district officials, as well as the approach to impact evaluation and the need to randomise the allocation of the grants.

The second step was a similar presentation to the authorities of villages selected to receive these grants. The presentation included a detailed description of the grants and its conditions (including that they could only be used for contracting extension services and for expenses directly related with training). This meeting was also used to obtain an expression of their interest in participating in the trial (which was expressed in all occasions).

Figure XX: Structure of the DLE intervention

As a third step, the project team organized a village meeting in each of the participating villages. During these meetings, the details of the intervention and the objectives of the grants were explained. In order to manage the grants at the village level (including formulating the extension demand as well as facilitating the training sessions), villages were requested to form a committee. Usually in the same meeting, participants were asked to express their priorities in terms of extension, leading to a rank of training topics. The final choice of the top 3 topics was usually done by voting. After the meeting, the committee formalized the need of extension in a form provided by the project team.

The next step of this pilot was the advertisement of the extension needs, as ranked by the village, in order to find potential providers of the extension services. This step was the responsibility of the project team and included the distribution of posters at local agricultural institutions (e.g. universities, vocational training centres, research centres and extension offices) as well as adverts on the local radio and social media.

The period of advertisement was approximately one month, after which all applications were transferred to the village committees for selection. After being selected, trainers submitted a budget for their training session, which needed approval by the committee and the project team.

The last step of the intervention was the provision of training services, after which the committee paid the trainers for their services.

When piloting this approach, we involved communities in decision making, which are not familiar with these kinds of decisions (only 36% reported similar previous experiences). Nevertheless, the participation in the village meeting to select the training topics was quite large, averaging more than 50% of the households in a village, with some differences between provinces (participation in Luang Prabang was 66%, higher than in Xiengkhuang , at 45%) and with women slightly under-represented (41% and 46% of the participants in the meetings were female in Luang Prabang and Xiengkhuang, respectively). Table 19 presents the selected topics.

Table 19: Summary of training requested and provided: 2017-2018

Grant round	1st	2nd	3rd
Delivery	Wet season 2018	Dry season 2018	Wet season 2019
Between survey rounds	W1/W2	W2/W3	W2/W3
Livestock health	30	18	0
Ruminant health	26	0	0
Poultry health	4	7	0
Livestock health	0	11	0
Livestock production & nutrition	6	12	18
Pig production	3	0	0
Livestock production	0	4	2
Forage production	3	8	8
Pig & poultry feed production	0	0	8
Crop production	3	3	13
Plant protection	3	3	0
Rice production	0	0	13
Other	1	5	5
Total	40	38	36

Note: In some villages, more than one training topic was funded from one grant

Table 19 reveals two main patterns of the villagers when selecting extension services. First, mostly livestock topics, such as health and management, were selected by the villages in the first two rounds. Second, only when the need for livestock training was met did farmers start selecting crop production topics.

Comparing these training topics with training offered by official extension services, we observe again that the concentration on topics of livestock husbandry is substantially larger in our approach (over two years around 74% and 47% livestock topics in the DLE approach and governmental extension, respectively), with official extension covering a larger diversity of topics (e.g. they include processing and soil protection). Perhaps reflecting this difference in emphasis, a much larger share of households participated in the DLE trainings than in the governmental extension trainings (see Table 20). The household survey data shows that the number of trained households is between two times and seven times larger in the treatment villages than in the control villages.

Table 20: Participation in training activities

Year	2018		2019	
	Control	Treatment	Control	Treatment
Number of participants in training	161	453	55	436
Number of households with any training	111 (28%)	272 (70%)	41 (10%)	264 (67%)
N	400	387	399	396

A second choice by the villages participating in the DLE intervention was the selection of the trainers. In 77.1% of the cases, trainers were selected in a second village meeting and in the remainder cases this choice was made solely by the committee. Reviewing information about this choice, we observe a strong influence of governmental extension on this decision. 40% of the villages relied on advice from the local extension officer for this decision. 77.1% of the villages reported that their main criteria for selecting the trainer was her/his connection to governmental extension. Not surprisingly, 69% of the selected trainers were governmental extension officers. Furthermore, as 88.6% of the trainers were hired for all three rounds of the grants, these villages did not make use of their ability to not select a trainer again. It seems that farmers when selecting a trainer rely on the familiar connection to the governmental extension officers, which reveals challenges for the promotion of pluralistic extension.

7.4.2 Main results

Randomisation of funding allows us to estimate the impact of this approach to the provision of extension services, with data on 36 treated villages being compared with 35 control villages. To a large extent, randomisation was successful in creating two identical groups at baseline, as we only find differences (at the 10% significance level) in terms of whether the household head is of Khmu ethnicity, number of adults, household size, livestock (TLU) and asset index (at household level); and road access in the wet season and number of extension visits (at the village level). In both sets of data, we cannot reject the null hypothesis that treatment status is uncorrelated with the set of individual and village variables (p-values of 0.125 and 0.124, for household and village variables, respectively). Similarly, the analysis of attrition between surveys shows that the attrition patterns are not correlated with treatment status.

We estimate the impact of the intervention using an ANCOVA specification, and present the results for two specifications: with and without unbalanced variables at baseline (at the 10% significance level). We estimate both Intent-to-Treat (ITT) effects and Local Average Treatment Effects (LATE). The latter focuses on the complying households in the intervention, which are the ones who participated in the training offered as part of this intervention or in the decision process. The main outcomes of the intervention are training participation, adoption of new technologies, social cohesion and food security.

As mentioned earlier, the number of households trained was higher in treated villages, a result that is confirmed in the first two columns of Table 21: the probability of receiving extension services for households in treated villages increases by around 40% and 60% in the first and

second year, respectively. We find a similar result for the number of training sessions and training days, which further shows that this approach increases the intensity of training.

Table 21: Treatment effects: Training participation

	(1)	(2)	(3)	(4)	(5)	(6)
	Training participation (1/0)		Training sessions		Training days	
VARIABLES	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
ITT						
No controls	0.409***	0.581***	0.728***	0.873***	0.864***	0.972***
	(0.0415)	(0.0442)	(0.0925)	(0.0818)	(0.117)	(0.0988)
With controls	0.394***	0.595***	0.680***	0.888***	0.796***	0.973***
	(0.0444)	(0.0488)	(0.0979)	(0.0906)	(0.119)	(0.0938)
LATE						
No controls			1.779***	1.501***	2.112***	1.672***
			(0.137)	(0.0855)	(0.229)	(0.122)
With controls			1.724***	1.491***	2.017***	1.635***
			(0.156)	(0.0901)	(0.245)	(0.109)
Observations	787	795	787	795	787	795
Control Mean	0.292	0.108	0.475	0.175	0.515	0.223

Note: SE are clustered at the village level. *** p<0.01, ** p<0.05, * p<0.1

One important question is how the extension services funded by the grants were evaluated by trainees. Table 22 presents the evidence on two of the criteria that may address that question: the importance of the training topic and respondent's evaluation of the knowledge gain from the training. It also presents evidence on the impact of these grants on the number of changes in practices due to the trainings, our measure of adoption. Results are overall supportive of the value of the approach piloted here: households evaluated the training topics as being more important and reported learning more. This positive evaluation seems to translate in the adoption of new technologies, which is 40% and 50% higher in treatment villages, in year one and two, respectively.

Table 22: Treatment effects: Perceived quality of trainings and adoption

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Importance		Knowledge gain		Adoption (1/0)	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
ITT						
no controls	1.016***	1.422***	0.637***	0.614***	0.163***	0.307***
	(0.104)	(0.108)	(0.0730)	(0.0585)	(0.0315)	(0.0349)
with controls	0.971***	1.448***	0.612***	0.642***	0.162***	0.298***
	(0.107)	(0.118)	(0.0743)	(0.0636)	(0.0335)	(0.0382)
LATE						
no controls	2.483***	2.445***	1.557***	1.056***	0.398***	0.528***
	(0.0905)	(0.0446)	(0.0798)	(0.0519)	(0.0684)	(0.0426)
with controls	2.461***	2.432***	1.552***	1.078***	0.411***	0.501***
	(0.0964)	(0.0486)	(0.0873)	(0.0528)	(0.0745)	(0.0427)
Observations	787	795	787	795	787	795
Control Mean	1.603	1.249	1.390	1.124	0.138	0.060

Note: SE are clustered at the village level. *** p<0.01, ** p<0.05, * p<0.1. Importance of the topic (columns 1 and 2) is measured using a four level Likert scale (with 4 indicating “very important“).Knowledge gain is measured using a three level Likert scale (with 3 indicating “much more knowledge”).

As suggested by the literature on CDD, participation in the decision process regarding the allocation of community funds may impact on social cohesion. Social cohesion is defined as the connectedness within a community and builds on the relationship between peer villagers and their relationship to political institutions (Chan et al., 2006). We collected data of three domains of social cohesion: trust, political efficacy and cooperation.

The first column of Table 23 reports the effect of the grants on participation in community meetings (which matches the first stage of LATE and our definition of compliers when evaluating the impact on social cohesion): approximately 60% of the households participated in the first meeting during which most of the decisions were made.

In columns 2 to 5, we report treatment effects on locus of control and trust. Decentralized funding of these grants leads to a reduction of external locus of control (powerful other) in the treatment group, although this effect seems sensitive to the inclusion of additional control

variables. We do not find any effect on trust within village, but we find a positively and precisely estimated effect on trust in outsiders.

Table 23: Treatment effects: Locus of control and Trust

	(1)	(2)	(3)	(4)	(5)
	Participation village meeting	Trust in peers (self-reported)	Trust in peers (trust game)	Trust worthiness in peers (trust game)	Trust in outsiders (self-reported)
ITT					
no controls	0.600***	-0.047	-0.020	-2.133	0.023**
	(0.028)	(0.053)	(0.071)	(1.829)	(0.011)
with controls	0.616***	-0.014	0.011	-2.826	0.024**
	(0.027)	(0.055)	(0.077)	(1.856)	(0.011)
LATE					
no controls		-0.078	-0.034	-3.550	0.039**
		(0.088)	(0.117)	(3.033)	(0.018)
with controls		-0.022	0.018	-4.581	0.039**
		(0.088)	(0.124)	(2.983)	(0.018)
Observations	795	795	795	795	795
Control Mean	0	0.321	2.581	63.207	0.013

Note: SE are clustered at the village level. *** p<0.01, ** p<0.05, * p<0.1

Table 24 presents the estimates of the impact of the grants on political efficacy and cooperation. We test villagers' perception of communal and district policy making being effective for their livelihoods. Households in treatment villages perceived that the implementation of communal decisions became less likely, an unexpected result that is potentially explained by dissatisfaction with the decision of the village meeting. In a regression model, we find a linear relationship between satisfaction with the decision in the first village meetings and the variable for implementation of communal decisions (coefficient: 0.126; p-value: 0.086).

Households in treated villages are more likely to report problems to district authorities (in this case, a hypothetical water supply problem), a results that confirms our earlier result of an increased trust in outsiders. With respect to cooperation at the village level (details about the self-reported outcome variables (columns 3 and 6) and the experimental outcomes (columns 4

and 5) can be found in Appendix A and B, respectively), the results are somewhat mixed: we do not detect an increase in days allocated to collective activities, or in own and (expected) cooperation by others in a public goods (PG) game. However, we find that the likelihood of cooperation when solving a (hypothetical) communal problem is larger in treatment villages.

Table 24: Treatment effects: Political efficacy and social capital

	(1)	(2)	(3)	(4)	(5)	(6)
	Implementation of communal decisions	Reporting to district authorities	Days community activities (last year)	Cooperation in PG game	Expected cooperation of others in PG game	Likelihood of cooperation
ITT						
no controls	-0.129**	0.113**	-0.946	0.019	-0.987	0.112*
	(0.053)	(0.051)	(0.914)	(0.069)	(0.725)	(0.057)
with controls	-0.167***	0.093*	-1.051	0.023	-0.791	0.098
	(0.059)	(0.049)	(0.822)	(0.072)	(0.735)	(0.060)
LATE						
no controls	-0.215**	0.189**	-1.578	0.032	-1.643	0.186**
	(0.089)	(0.083)	(1.504)	(0.113)	(1.221)	(0.092)
with controls	-0.271***	0.151**	-1.705	0.037	-1.282	0.159*
	(0.097)	(0.076)	(1.313)	(0.115)	(1.186)	(0.095)
Observations	795	795	795	795	795	795
Control Mean	2.579	3.358	12.078	2.218	22.383	3.358

Note: SE are clustered at the village level. *** p<0.01, ** p<0.05, * p<0.1

The final outcome (and aim) of this intervention is to improve food security, measured using the Food Consumption Score (FCS), a score based on a weekly recall of a household's diet, developed by the World Food Program (WFP) with specific weights for Lao food consumption habits (WFP, 2007). Food insecurity is defined as a FCS lower than a threshold of 36. In addition, we estimate the impact of this intervention on shortage of rice consumption (in number of months during the last year). The results are presented in Table 25.

The pattern identified by these results suggests that households respond to the program by first reducing consumption in order to make any adaptations to changes in technology (hence FCS

decreases and food insecurity increases in year 1), before benefiting from these changes through improvements in consumption (in year 2). This is a common pattern for interventions that promote household investment in the absence of well-functioning credit markets (which, then, force households to rely on savings to finance investments). Although these impacts are non-negligible (reduction in food insecurity of approximately 5% of the mean value in control villages) the estimates are relatively imprecise, which may also reflect the timing of the survey (shortly after the main rice harvest, when food insecurity is expected to be lowest).

Table 25: Treatment effects: Food security

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	Food Consumption Score		Food Insecurity (FCS < 36)		Rice shortage	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
ITT						
no controls	-1.580	1.825**	0.025	-0.010	-0.006	-0.013
	(1.557)	(0.863)	(0.030)	(0.020)	(0.013)	(0.042)
with controls	-2.758*	1.133	0.037	-0.003	0.001	0.008
	(1.576)	(0.942)	(0.029)	(0.020)	(0.014)	(0.040)
LATE						
no controls	-3.852	3.138**	0.060	-0.017	-0.015	-0.022
	(3.728)	(1.416)	(0.072)	(0.034)	(0.031)	(0.071)
with controls	-6.993*	1.902	0.095	-0.004	0.003	0.014
	(3.984)	(1.478)	(0.072)	(0.033)	(0.034)	(0.065)
Observations	787	795	787	795	787	795
Control Mean	52.292	50.313	0.113	0.085	0.043	0.170

Note: SE are clustered at the village level. *** p<0.01, ** p<0.05, * p<0.1

7.4.3 The impacts of training on livestock production

Most villages selected livestock health and management topics as the first or second training priority. The strong interest in information about livestock husbandry likely reflects the current increase in livestock production in the northern uplands of Lao PDR, a transformation driven by the increasing domestic demand of meat in urban areas and in neighbouring countries (Vietnam and China).

Given the importance of these topics, particularly for larger ruminants (cattle and buffalo), we analyse the impact of this approach on outcomes specific to livestock production in more detail. We adjust the model specification of the ANCOVA for the livestock outcomes. To focus our model only on households who actually raised cattle and buffalos (603 of 852 households), we include an indicator variable for non-livestock producers at the beginning of the intervention. Additionally, we define as compliers those households who participated in a training on livestock health or management.

Table 26 reports the impact of the intervention on livestock management. Most of the training sessions exposed producers to more efficient and output oriented production systems, such as fenced pasture and cowsheds, which contrast with more basic management systems that often involve free or guarded grazing. In columns 1 to 4, we report the effect of the intervention on the adoption of these innovative management systems. We find a significantly positive effect of the intervention in both seasons, but slightly larger in the wet season.

The largest challenge for livestock producers is the dry season, when forage becomes scarce. In many cases this leads to livestock losing weight and becoming more susceptible for diseases. Production of fodder in the wet season is one of the recommended practices to overcome this problem. In column 5, we find a large and precisely measured increase of fodder production caused by the intervention.

Table 26: Treatment effects: Livestock management

	(1)	(2)	(3)	(4)	(5)
	Non-herding – Dry season		Non-herding – Wet season		Fodder production
VARIABLES	Year 1	Year 2	Year 1	Year 2	Year 2
ITT					
No controls	0.0765**	0.0435	0.101**	0.0952**	0.127***
	(0.0331)	(0.0263)	(0.0490)	(0.0471)	(0.044)
With controls	0.0338	0.0144	0.0214	0.0267	0.143***
	(0.0307)	(0.0255)	(0.0435)	(0.0433)	(0.044)
LATE					
No controls	0.180**	0.102*	0.238**	0.223**	0.298***
	(0.0768)	(0.0607)	(0.117)	(0.110)	(0.098)
With controls	0.0838	0.0328	0.0531	0.0611	0.326***
	(0.0747)	(0.0567)	(0.107)	(0.0965)	(0.097)
Observations	787	795	787	795	795
Control Mean	0.112	0.081	0.292	0.298	0.539

Note: SE are clustered at the village level. *** p<0.01, ** p<0.05, * p<0.1

The other area of large interest of farmers was livestock health. We focus here on outcomes related to the use of vaccines for infectious diseases. The main infectious diseases of cattle and buffaloes in the area are haemorrhagic septicaemia (HS) and foot-and-mouth disease (FMD). In Table 27, we report changes in the number of farmers who vaccinated their livestock and the number of animals vaccinated against these diseases.

We find positive treatment effects for the adoption of both vaccines, especially in the second year. For the vaccines against HS, which had a larger penetration already at the beginning, the farmers applying the vaccine and the number of immunised animals increased by 30.4% and 50.0% in the second year, respectively. Adoption and penetration of the FMD vaccine rose by 51.5% and 65.9% in the second year, respectively. These very positive effects contrast with often disappointing results of general vaccination campaigns and demonstrate a large interest of livestock producers in using vaccines against HS and FMD.

Table 27: Treatment effects: Livestock health

	(1)	(2)	(3)	(4)	(5)	(6)
	HS vaccine use		HS vaccinated Animals	FMD vaccine use		FMD vaccinated animals
	Year 1	Year 2	Year 2	Year 1	Year 2	Year 2
ITT						
No controls	0.062	0.117**	1.533**	0.077*	0.111**	1.223**
	(0.049)	(0.053)	(0.634)	(0.044)	(0.043)	(0.500)
With controls	0.014	0.080	1.179**	0.039	0.084*	0.947*
	(0.051)	(0.055)	(0.510)	(0.044)	(0.049)	(0.477)
LATE						
No controls	0.145	0.274**	3.591**	0.182*	0.261**	2.864**
	(0.113)	(0.125)	(1.504)	(0.103)	(0.103)	(1.193)
With controls	0.035	0.183	2.695**	0.096	0.192*	2.180**
	(0.123)	(0.123)	(1.159)	(0.107)	(0.110)	(1.096)
Observations	787	795	795	787	795	795
Control Mean	0.328	0.263	2.356	0.237	0.163	1.436

Note: SE are clustered at the village level. *** p<0.01, ** p<0.05, * p<0.1

The natural follow-up question is whether these improvements in management and health practices, led to measurable improvements in other outcomes. We focus on livestock in TLU, herd size of large ruminants, mortality rate and the number of large ruminants sold (Table 28).

The intervention did not increase livestock ownership (either in TLU or in large ruminants) or sales. However, mortality rates significantly reduced among those households who participated in livestock training. We can calculate these benefits in monetary terms. In the second year, 188 farmers participated in livestock training and owned on average 8.9 large ruminants. The cattle price during this year was on average 3.8 million LAK. The reduced mortality rate of 0.029 percent translates into a reduced loss of 184 million LAK over all participants in livestock trainings. These benefits alone exceed the total amount of training funds paid to all villages in three years (135 million LAK).

Table 28: Treatment effects: Livestock outcomes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
	Livestock (TLU)		Herd size (cattle and buffalo)		Mortality rate (cattle and buffalo)		Number of cattle and buffalo sold	
	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2	Year 1	Year 2
ITT								
without control	0.318	0.160	0.144	0.208	0.001	-0.014	0.006	0.277
	(0.402)	(0.512)	(0.303)	(0.372)	(0.016)	(0.010)	(0.144)	(0.185)
with control	0.023	-0.074	0.0617	0.101	0.010	-0.013	-0.051	0.148
	(0.440)	(0.532)	(0.313)	(0.359)	(0.017)	(0.008)	(0.131)	(0.146)
LATE								
without control	0.757	0.375	0.341	0.487	0.003	-0.032	0.013	0.649
	(0.948)	(1.183)	(0.708)	(0.859)	(0.038)	(0.023)	(0.337)	(0.417)
with control	0.058	-0.169	0.154	0.232	0.024	-0.029*	-0.127	0.338
	(1.075)	(1.201)	(0.770)	(0.805)	(0.043)	(0.017)	(0.322)	(0.320)
Observations	787	795	787	795	787	795	787	795
Control Mean	9.586	9.411	6.263	6.391	0.0799	0.0453	0.672	0.672

Note: SE are clustered at the village level. *** p<0.01, ** p<0.05, * p<0.1

7.4.4 Financial sustainability

The implementation of this approach requires a relatively small funding (the total cost is approximately AU$5 per household). A natural question is whether beneficiary households are willing to pay for the provision of these services, contributing to its financial sustainability. To address this question, and as part of the second follow-up survey (ie, after the provision of three rounds of grants), we collected information about the households' willingness to pay for extension services.

Table 29 reports some summary statistics of the answers provided by the respondents. Nearly all household heads stated that they were willing to contribute to a training fund. The value of the contributions, when extrapolated to the entire village, were approximately 2.5 million LAK (ie, almost the double of the piloted training fund, which was set at 1.25 million LAK per village). Despite heterogeneity in contributions and in the size of villages, almost all villages (93%) would be capable of collecting more than the funds used in the intervention. Although differences between WTP and actual contributions are expected, this data is encouraging regarding the financial sustainability of this type of work.

Table 29: Willingness to pay for a training fund – Individual and extrapolated to village level

	N	Mean	SD
Individual			
Contribute to a training fund (1/0)	787	0.956	(0.206)
Willingness to pay (1,000 LAK)	787	38.38	(42.49)
Village contribution			
Willingness to pay (1,000 LAK)	71	3,639	(2,452)

7.5 Insurance against weather shocks

The methodological steps needed to define an insurance against covariate shocks were presented in Section 5.4. The index was designed using data from the villages included in the Demand Led Extension just described, taking advantaged of detailed data on yield, as well as on other village level information (average altitude and slope within 5km of the village centroid, as well as soil characteristics).

As index we use data on the Normalized Difference Vegetation Index (NDVI) from ORNL DAAC website that provide MOD13Q1 Vegetation Indices from the MODIS satellite every 16 days for pixel at a maximum resolution of 250m per side. We use data for the period 2000-2018, and define a village as a polygon with 2.25 km per side centered on the village coordinates, assuming that all plots in a village are within this area, which reflects the fact that most plots are in fact fairly close to the village center. We find no evidence that NDVI would change significantly when we consider larger areas (polygons of 5km and 7.5km per side) suggesting that our analysis is robust to this assumption. Figure 10 presens the pattern of NDVI for one village in our survey, which essentially follows rice production: lower in the first part of the year, increasing after the transplanting stage (April/May, in the case of rice in northern Laos),

reaching its peak at the end of reproductive stage (September), and decreasing at the time of harvest (late November-December).

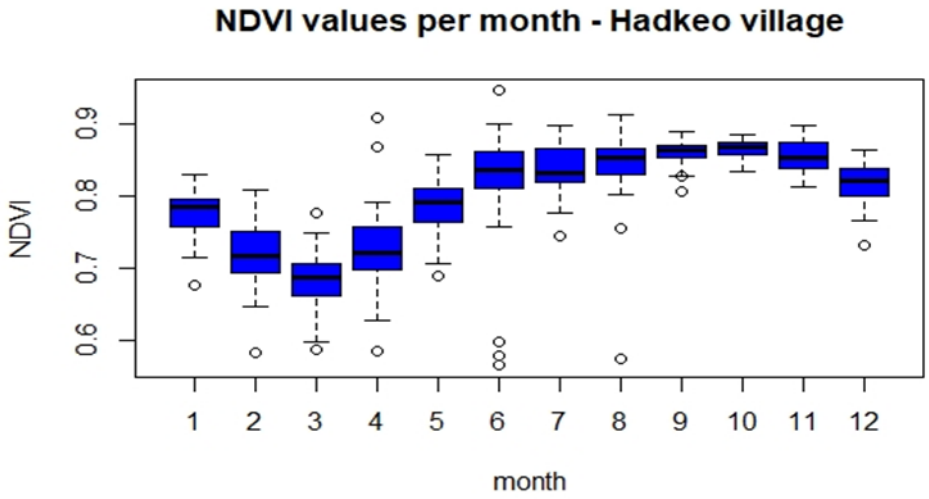


Figure 10: **boxplot of NDVI values per month of Hadkeo village.**

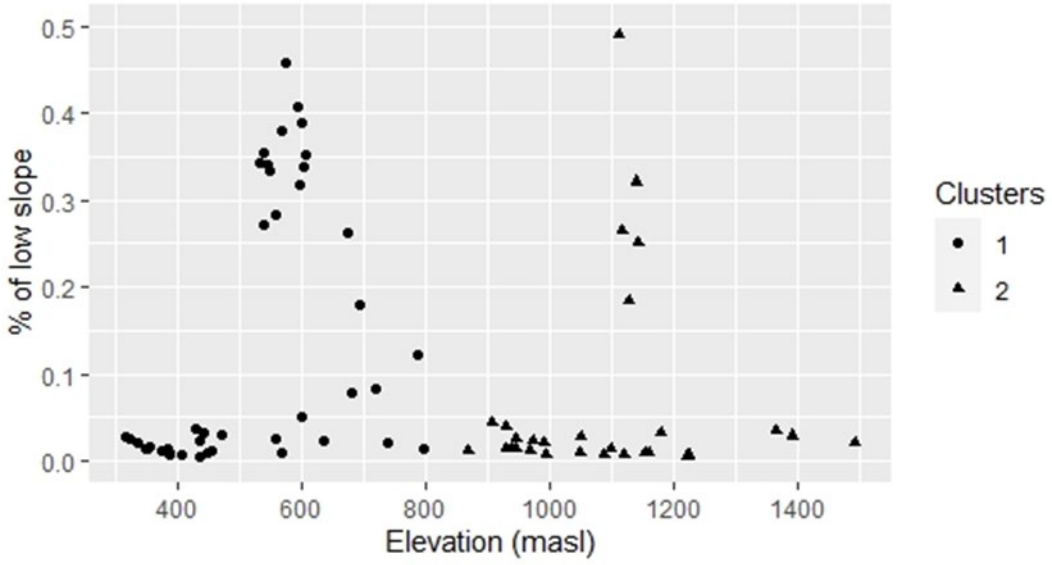


Figure 11: village clustering as a function of environmental characteristics

The definition of more homogeneous production conditions in terms of biophysical conditions is expected to lead to differences in the relation between covariate shocks (proxied by average yield at village level) and household yield. This is in fact what we observe when we estimate a OLS regression between these two variables for the whole sample and for each cluster separately, as shown in Table 30: not only the effect of covariate shocks on yield is substantially different across clusters, the overall statistical fit of this model is much higher in cluster 1 than in cluster 2, suggesting that index insurance has a much smaller role to play in the latter.

Table 30: Landscape heterogeneity and heterogeneity of effect of covariate shocks

	Whole sample	Cluster 1	Cluster 2
Average Yield (village)	0.935***	0.949***	0.895***
Constant	0.4953*	0.396	0.800.
Adj. R^2	0.372	0.453	0.232
N	1683	964	719

Note: ***p≤0.01, ** p≤0.05, *p≤0.10

The estimates of the statistical relation between yield and index (NDVI) were obtained using different statistical methods (OLS, Stepwise regression, Variance Inflation Factor, LASSO, Elastic Nets, Principal Component Analysis) and different specifications of the Index, reflecting the novelty in the use of this data and the uncertainty in the literature regarding the best way to express the relation between NDVI and rice yield. In particular, we consider NDVI, Standardized Vegetation Index (Peters et al, 2002) and NDVI minus NDVI value at the beginning of the growing season (as a way to isolate the photosynthetic effect of rice from that of permanent vegetation). We also included environmental variables (soil properties) as additional control variables. The best model, out of the 36 possible specifications, for the whole sample and for each cluster, was then selected on the basis of the RSME in the test sample (formed by 20% of the original observations, randomly selected from the entire sample).

Using this information, we can then define a different index insurance for both the entire sample and each cluster separately. As discussed in section 5.4, this requires the definition of the most appropriate trigger level, payout structure and allows us to quantify the associated Basis risk. Figure 12 plots observed values of yield against predicted yield, using the model selected for the whole sample and where, for simplicity we set the trigger (represented by the blue line), at 80% of the average yield, allowing us to get a visual idea of the importance of prediction error.

Households to the left of the vertical line (predicted yield below the trigger) will receive an indemnity. The black points, in the third quadrant in Figure 12, represent households that experienced a loss and were correctly paid, while red points (in the first quadrant) represent those that did not experience a loss and were correctly not paid. A perfect index insurance would have all observations in these two quadrants. The blue points, in the fourth quadrant, represent households that did receive an indemnity even though they did not experience a loss, while the green points (in the second quadrant) represent households that did not receive any indemnity even though they experienced a loss. The size of this last group determines the importance of Basis risk, which can be quantified for different values of the trigger value and, importantly for our discussion of the relation between landscape heterogeneity and the feasibility of these products, across the different sub-samples.

The results of this analysis for two different values of the trigger (0.70 and 0.90) are presented in Table 31. Two main conclusions emerge from the results presented in this Table. The first is that accounting for landscape heterogeneity (in this case using a clustering approach) has the potential to significantly improve the design of this type of contracts. Contracts can now be defined for either cluster that exhibit much lower premiums for similar values of Basis risk than a contract defined for the entire sample. The second conclusion is that even with the improvement introduced by addressing landscape heterogeneity, index insurance is still likely to be too expensive to be bought without additional public subsidies.

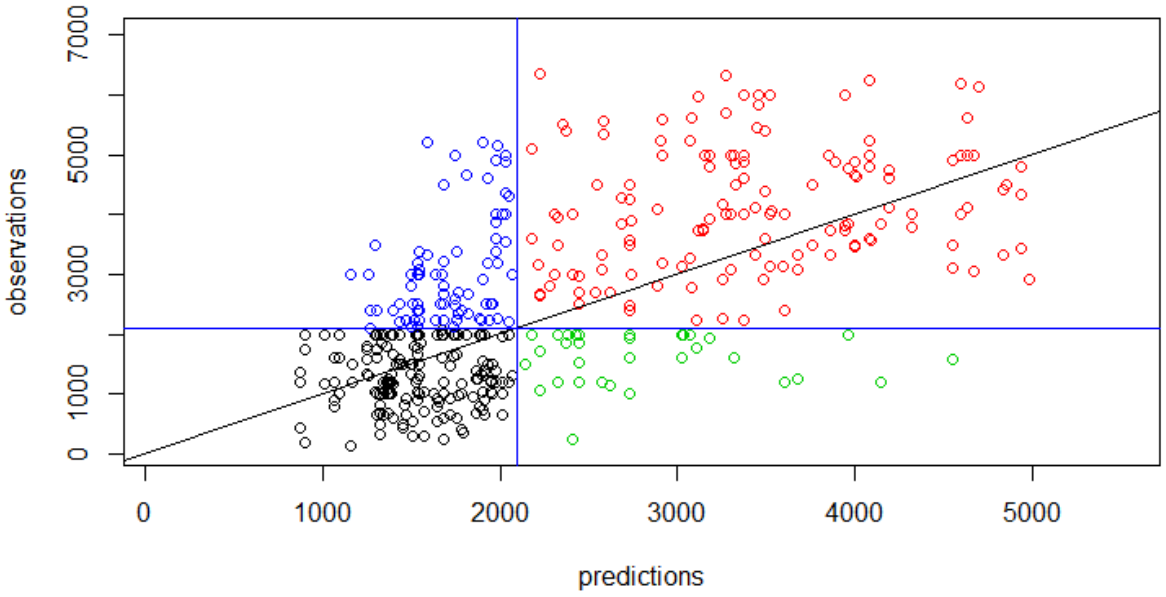


Figure 12: observed yield vs predicted yield, and the definition of basis risk

Table 31: The effect of accounting for landscape heterogeneity on basis risk and premiums

	All			Cluster 1			Cluster 2		
Trigger	Negative Basis risk (%)	Positive Basis risk (%)	Premium (% average yield)	Negative Basis risk (%)	Positive Basis risk (%)	Premium (% average yield)	Negative Basis risk (%)	Positive Basis risk (%)	Premium (% average yield)
0.70	0.274	0.125	0.059	0.219	0.108	0.080	0.265	0.087	0.007
0.75	0.142	0.137	0.082	0.199	0.095	0.097	0.213	0.126	0.016
0.80	0.107	0.215	0.110	0.182	0.109	0.114	0.189	0.182	0.028
0.85	0.104	0.221	0.138	0.103	0.136	0.132	0.152	0.312	0.045
0.90	0.099	0.250	0.169	0.075	0.127	0.149	0.126	0.311	0.065
0.95	0.074	0.260	0.201	0.072	0.134	0.168	0.127	0.325	0.088
N	1683			964			719		

Notes: Calculations of basis risk and premium are based on elastic net predictions of yield in the test sample at different levels of the trigger. N is the number of observations on which the Basis risk and Premium are calculated. Assuming an actuarially fair contract and price normalized to 1, the premium is the sum of the differences between the predicted yield and the trigger for all observations for which the expected yield is lower than the trigger. Premia are expressed as percentage of the average yield of the sample.

7.6 Quantifying the effect of regulatory choices on market outcomes

Following on the conclusion that provincial and district officials were aware of the wider impacts of regulation choices, and in particular of the potential negative effects on producers' prices of reducing competition in local markets, the research team surveyed all districts in the north of Lao PDR to collect information on market regulation of three main commodities (rice, cattle/buffalo, and maize) over the previous two years (2016/17 and 2017/18). In addition to information on the organization of trade (distinguishing between three market structures: free entry, a few traders in the district and one single licensed trader; in the case of maize we also enquired about the importance of contract agriculture), we also collected data on volume and value of trade, taxes collected and prices paid to producer. Finally, in those pairs of commodities/district that changed the way trade was organized in the last 3 years, we asked the main motivation for this change.

The survey was sent via email/fax in April 2019 and was not expected to take more than 15-20 minutes to fill. In June 2019, district authorities that had not sent a response, were reminded of this survey, which was considered closed in August 2019. In total we received a response from 44 DAFO (a 62% response rate). The data on maize contained too many incoherencies (possibly because of the way that contract was included as an additional alternative) and we don't present the results of this analysis. The main results are summarized in Table 32.

Table 32: Market structure in northern Lao PDR: rice vs cattle

Commodity	Rice	Cattle
Important commodity[a)]	25	36
Market structure [b)]		
One licensed buyer	6	4
Limited licensed buyers	19	18
Free Entry	43	45

Note: a) out of 44 responses, b) for those districts where the commodity was important, we collected two observations per district (one per year).

Using this data it is possible to obtain a first estimate of the effect of market structure on commodity price by using OLS to estimate a simple linear relation between price of each commodity and market structure, while additionally controlling for year fixed effects. The results are presented in Table 33.

Table 33: The effect of market structure on producers' prices

Commodity	Rice	Cattle
One licensed buyer	153	-3087966 ***
Limited licensed buyers	-195	59539
Year	-165	176584
Constant	334943	-3.52e+08
N	50	72

Results from a random effects regression. Standard errors clustered at province level.

*** p<0.01, ** p<0.05, * p<0.1

Although much care must be placed in the interpretation of these results, and they should not be interpreted as causal, they are suggestive that policy choices regarding how to organize markets have impacted the prices received by producers. In particular, monopsonies have hurt cattle/buffalo producers: the effect is both large and precisely estimated. A solution to this problem will need to balance the political economy constraints identified during out interviews with district officials (and in particular the need to raise enough tax revenue) with the potential benefits (for producers) of promoting competition in the cattle trade sector.

7.7 Accounting for behavioural biases

Following from results, discussed above, that heterogeneity in terms of a scale of self-control predicted food insecurity (although other behavioural biases, such as mental accounting, had no explanatory power), we collected additional data aimed at exploring whether personality psychology (which includes the analysis of differences in cognitive capacity) can contribute to explain differences in outcomes such as vulnerability to food insecurity, the capacity to take advantage of new market opportunities or the adoption of technologies. This section presents some preliminary answers to those questions.

Extensive treatments of the contribution of behavioural economics and cognitive psychology to the analysis of development can be found in Kremer, Rao and Schilbach (2019) and Dean et al (2020).

7.7.1 Self-control predicts vulnerability to food insecurity

Vulnerability is defined as "the likelihood that a shock will result in decline in well-being" (World Bank, 2001, p.139), which makes the concept's future-orientated and probabilistic nature explicit. Similar concerns about the temporal dimension of deprivation are also present, in an even more explicit way, in the definition of food security, to be achieved when ``all people *at all times* have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life'' (World Food Summit,1996, our emphasis). For this study, vulnerability to food insecurity is measured as subjective expectations of future food insecurity, hence directly addressing the problem of

quantifying the possibility of future deprivation that is at the heart of the concept of vulnerability. More precisely, it is quantified by asking respondents about their expectations of not having enough food during a specific time period into the future.

Among the variables used to explain vulnerability, most attention has been devoted to asset ownership and management in times of distress (Moser, 1998) or, more generally, access to different coping mechanisms (Maxwell et al., 1999). However, little attention has been paid to the potential importance of lack of self-control, i.e, the difficulties of sticking to plans. This is surprising when considering the institutional context in which households in developing countries make their decisions. As producers, agricultural households are generally self-employed and consequently unconstrained by the disciplining devices that may reduce procrastination in other industries. As consumers, many households rely on one major source of income, received at one time, which is then consumed throughout the year while formal savings opportunities are, in many circumstances, limited. The existence of ample opportunities to deviate from predefined plans is clear. This is the question addressed in Meyer and Santos (2020).

Self-control is the mental capacity to align actions with “cold” goals, overcoming hot negative “desires” (i.e, temptation). In this very general approach, self-control relies on the core executive function of inhibitory control, the mental process that allows us to block out distractions, control impulsive urges and override automatic responses (Diamond, 2013). This cognitive capacity is quantified through the widely used Stroop test (Stroop, 1935) in which individuals are asked to control the tendency to respond to a task automatically while inhibiting an interfering stimulus (Dadon and Henik, 2017). In this task participants are asked to respond to a stimulus and block an irrelevant stimulus. Inhibitory control is measured as the delayed response time to the stimulus.

The relation between self-control and vulnerability to food insecurity is estimated with the following equation:

$$V_{ij} = \beta_0 + \beta_1 SC_{ij} + X_{ij}'\theta + Z_j'\gamma + \varepsilon_{ij}$$

Where V_{ij} stands for vulnerability of individual i in village j, SC is self-control, our main variable of interest, X_{ij} and Z_j stand for household and village covariates respectively and ε_{ij} stands for the error term. Standard errors are clustered at the village level.

Table 34 presents the OLS estimates. First, the estimated coefficient without covariates is reported. In column 2, covariates that are typically associated with vulnerability (namely individual and village characteristics) to improve the precision of these estimates are added. In columns 3 and 4, other variables, either other executive functions or economic preferences, are included to test if the estimates can be interpreted as a causal effect or simply reflecting the effect of other variables (omitted variable bias). In the last column, controls for Social Desirability Bias (SDB) (based on Hart et al. (2015), see also Meyer and Santos (2020)) are added to address for a willingness to provide answers that may be deemed (by the respondent) as more desirable, as we rely on subjective assessments of vulnerability. The effect estimated in column 1 is fairly large: a one standard deviation reduction in response time (recall, higher self-control leads to lower response times) leads to a reduction in the subjective expectation of being food insecure for at least one month of more than 1.2%. The unconditional mean of this variable is approximately 17%. Furthermore, the other results allow us to conclude that the effect of self-control seems robust to the other potential biases.

Table 34: Explaining vulnerability to food insecurity

	(1)	(2)	(3)	(4)	(5)
Self-control	1.213	1.774**	1.875**	1.795**	1.793**
	(0.818)	(0.830)	(0.822)	(0.856)	(0.851)
Individual and village characteristics	No	Yes	Yes	Yes	Yes
Other executive functions	No	No	Yes	Yes	Yes
Time and risk preferences	No	No	No	Yes	Yes
Social Desirability Bias	No	No	No	No	Yes
N	807	734	732	691	691
R^2	0.002	0.179	0.179	0.182	0.185

Note: Standard errors in parentheses are clustered at village levels. * p < 0.10, ** p < 0.05, *** p < 0.01*

The effect of self-control on vulnerability to food insecurity is identified by examining the sensitivity of the estimates to reasonable assumptions about the importance of unobservables (Oster, 2019), given the set of observable characteristics, that include other cognitive functions (i.e. short-term memory, working memory, attention, cognitive planning, flexibility and fluid intelligence), economic preferences (present bias and risk) and other individual characteristics (i.e. household demographic characteristics, wealth and business ownership) and village characteristics (i.e. distance and access to markets and to local authorities, proxied by the existence of all-year round roads) previously studied in this literature.

Table 35 presents the bounding set of the coefficient stability test (for the models presented in Table 34, columns 2 to 5) is reported, namely the earlier estimate of β and the analogue estimates of a regression which includes both observable and potentially unobservable confounding covariates, labelled β^*. Two assumptions are necessary to estimate β^* (see Oster, 2019): firstly, that the covariance of unobservables and observables with self-control are the same and secondly the R^2 of this regression is restricted to be 1.3 times larger than the R^2 of the regression with only observables.

Table 35: Analysing the stability of the effect of self−control

	Model 2		Model 3		Model 4		Model 5	
	Coeff	R^2	Coeff	R^2	Coeff	R^2	Coeff	R^2
β	1.755**	0.180	1.860**	0.181	1.783**	0.183	1.776**	0.186
β^*	1.634	0.234	1.698	0.235	1.635	0. 238	1.630	0.242
$\beta^* = 0$	0	1	0	0.875	0	0.943	0	0.976

Note: Standard errors in parentheses are clustered at village levels. * p < 0.10, ** p < 0.05, *** p < 0.01*

The identified sets do not include zeros, which means that, although the presence of omitted variables cannot be ruled out by design, its effect (if any) is not important enough to invalidate

our conclusion about the importance of self-control in shaping vulnerability to food insecurity. This conclusion is reinforced by the estimates of the values of R2s for regressions including unobservables for which the interval would contain zeros. These values, reported in the third row of Table 35 indicate that unobservables would need to be more than four times more important than the large set of observables that were already used in explaining vulnerability to food insecurity, for the estimated effect of self-control to be affected by parameter instability.

7.7.2 Cognitive capacity predicts market orientation

Commercialisation is a central orientation of agricultural policy in Lao PDR. But not every household engages with new market opportunities to the same extent. McKinley, Santos, Meyer and Yan (2020) examine the relative importance of cognitive capacity, measured using the same set of variables described above, in explaining heteregoneity in this behaviour, while accounting for a large set of confounders typically examined in studies of market participation (assets, demographic characteristics, community characteristics related with transaction costs, as well as economic preferences). They focus on the case of cattle, a major commodity whose value has greatly increased due to greater demand from external markets (most notably, Vietnam and China), part of what Delgado et al (2001) call the livestock revolution.

Producing cattle is not a new activity in the rural areas of Lao PDR, and an extensive literature studies its role and importance, noticeably as a saving mechanism (Harding, Warner et al. 2007). Producing cattle for a relatively large and distant foreign market is, however, new -- and this analysis is then related, more generally, with a discussion of the characteristics of the entrepreneur (defined as someone who is willing and capable of “try[ing] new things” as in Schumpeter (1947) or who has “the ability to deal with disequilibria” as in Schultz (1975)).

In tandem with government efforts to improved production and marketing conditions (Phonvisay, Vanhnalat et al. 2016), producers adapted to new opportunities in a very dynamic way: as shown in figure 13, in 2018, at the time of the survey, approximately 75% of households in our sample produced cattle (against less than 20% in 1990). However, the pace of this change shows remarkable differences: while the percentage of our sample raising cattle increased gradually (~ 1% per year) during the period 1990-2014, there is a noticeably quicker adoption during the period 2014 – 2018, when the share of cattle producers increased by approximately 5% per year. Simultaneously, this increase is accompanied by an increase in the importance of producing for the market, which grew to 39% of producers in 2018 (from a much lower share of 9% in 1990). It seems that households in our sample not only increased their wealth in terms of livestock (accompanying the general reduction in poverty in the country since the 1990s) but that an increasing fraction of producers see themselves as actively recognizing and taking advantage of the new market opportunities.

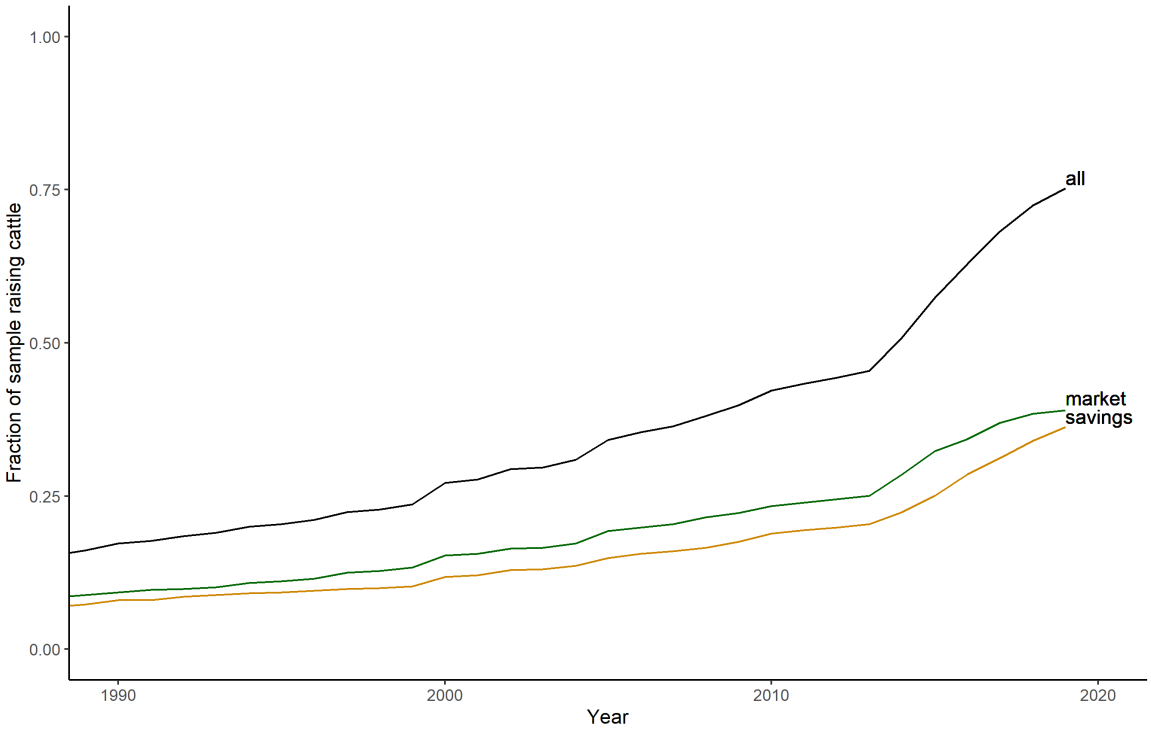


Figure 13: share of households raising livestock (distinguishing between market and savings as main objective of the producer)

Distinguishing three potential types of producers (livestock producers oriented to the market or entrepreneurs, livestock producers oriented to savings or traditional producers, and non-producers), the analysis starts with a presentation of descriptive statistics of each type, which is presented in Table 36. The first conclusion drawn from this table is that entrepreneurs are systematically different from traditional producers and non-producers in *all* measures of cognitive capacity. In all cases, entrepreneurs performed better than other households in the different tasks used to measure their executive functions. In contrast, we do not find a difference in terms of risk aversion and only statistically weak differences in terms of time preferences, with entrepreneurs being less patient than traditional producers. The second conclusion is that there are no large differences between entrepreneurs and traditional producers in terms of demographic characteristics, wealth (land and assets), or access to labour. Entrepreneurs had slightly larger farm sizes and greater access to young female labour than traditional producers, but all other wealth and demographic characteristics were the same.

Table 36: Characterizing entrepreneurs

	(1) Cattle (Market) Entrepreneurs		(2) Cattle (Savings) Traditional		(3) No Cattle Non-producers		Difference	
	Mean	SD	Mean	SD	Mean	SD	(1)-(2)	(1)-(3)
Household Head characteristics								
Cognitive planning	-0.11	1.31	-0.90	1.70	-0.82	1.67	0.79***	0.71***
Fluid intelligence	0.14	0.96	-0.06	1.07	-0.07	0.94	0.20**	0.21**
Inhibitory control‡	-0.07	0.11	-0.09	0.12	-0.08	0.10	0.02**	0.01
Working memory	0.15	0.95	-0.12	0.98	-0.05	1.04	0.27***	0.20**
Cognitive flexibility	0.22	0.89	-0.13	1.04	-0.13	1.04	0.35***	0.35***
Attention‡	0.20	0.84	-0.18	1.08	-0.07	1.11	0.38***	0.27***
Risk aversion	1.79	2.53	1.72	2.50	2.04	2.68	0.08	-0.25
Discount rate	0.17	0.14	0.15	0.13	0.16	0.14	0.02*	0.00
Schooling	5.39	2.85	5.38	2.89	5.49	3.24	0.01	-0.10
Age	47.81	12.31	47.47	12.83	45.39	13.21	0.35	2.42**
Male	0.97	0.16	0.97	0.17	0.94	0.24	0.00	0.03*
Literacy	0.92	0.27	0.90	0.31	0.89	0.31	0.03	0.03
Household characteristics								
Farm size (ha)	3.17	3.20	2.79	2.48	3.03	2.73	0.37*	0.14
Forest size (ha)	0.96	2.15	0.78	1.61	0.47	1.10	0.18	0.50***
Agricultural assets	0.13	1.06	0.11	1.04	-0.28	0.80	0.02	0.41***
Male labor (13-17)	0.38	0.62	0.41	0.63	0.28	0.56	-0.03	0.10**
Female labor (13-17)	0.46	0.68	0.33	0.62	0.39	0.81	0.13**	0.08
Male labor (18-60)	1.72	0.98	1.74	1.00	1.36	0.82	-0.01	0.37***
Female labor (18-60)	1.75	0.96	1.66	0.88	1.52	0.75	0.09	0.23***
Total labor	4.32	1.83	4.14	1.77	3.55	1.74	0.18	0.77***
Dependency ratio	1.01	0.82	0.99	0.82	1.01	0.71	0.02	0.01
N	**290**		**258**		**163**			

Note: '***', '**', and '*' are significant at 1%, 5%, and 10% respectively. ‡: We use the symmetric values of inhibitory control and attention so that higher values indicate better performance in the task.

In short, it seems that the decision to produce for the market (i.e., being an entrepreneur) versus for savings (the traditional activity), mostly reflects differences in producers' cognitive functioning. A natural follow up question is whether these two types of producers do things differently, either with respect to production or the way that cattle are marketed.

Production decisions of entrepreneurs and traditional producers are compared in Table 37. Entrepreneurs have larger herds and receive higher revenues from cattle production, but this difference is primarily driven by the number of cattle sold, as we cannot detect any difference in the price they receive for the animals they sell. Entrepreneurs also differ in how they manage herd size, being more likely to breed cows and restock through births, whereas traditional producers are more likely to purchase cattle to increase their herd size, presumably when benefiting from a positive shock to income. What is perhaps surprising is that there are not many other differences in management – entrepreneurs are not more likely to use modern breeding techniques, allocate resources to the production of forage or silage. They are even less likely to use preventative care, such as vaccinating their cattle against foot and mouth disease (a typically non-fatal disease), although they are slightly more likely to use a curative treatment.

There are, however, noticeable differences in marketing behaviour between entrepreneurs and traditional producers (Table 38). The data shows that, in general, entrepreneurs are more engaged in marketing activities than traditional producers. A higher percentage of entrepreneurs sell their cattle to multiple traders, in village markets. They were also more likely to check the price of cattle before a sale, especially by contacting a trader directly, and also more likely to bargain over the price with traders.

Table 37: Differences in production technology: entrepreneurs vs. traditional producers

	(1) Cattle (Market) Entrepreneurs		(2) Cattle (Saving) Traditional		Difference
	Mean	SD	Mean	SD	(1)-(2)
Herd Size	10.06	(9.07)	7.62	(6.85)	2.44***
Cattle Purchased (% yes)	0.109	(0.312)	0.239	(0.428)	-0.131***
Number of Cattle Purchased	0.412	(1.47)	0.517	(1.27)	-0.106
Number of cattle Born	2.42	(2.4)	1.95	(1.95)	0.47***
Cattle Sold (% yes)	0.551	(0.498)	0.363	(0.482)	0.188***
Number of Cattle Sold	3.59	(3.3)	2.15	(1.83)	1.44***
Cattle Revenue	15,109.91	(13192.24)	9,951.51	(9858)	5,158.40***
Price per cattle	4,717.62	(2132.28)	4,746.79	(2459.92)	-29.17
Controlled Mating (% yes)	0.041	(0.198)	0.023	(0.151)	0.018
Grow Fodder (% yes)	0.415	(0.494)	0.459	(0.499)	-0.044
Purchase Fodder (% yes)	0.003	(0.058)	0.00	(0.00)	0.003
Grow Silage (% yes)	0.01	(0.101)	0.008	(0.088)	0.002
HS Vaccine (% yes)	0.476	(0.5)	0.456	(0.499)	0.021
Foot and Mouth Vaccine (% yes)	0.293	(0.456)	0.436	(0.497)	-0.144***
Parasite Vaccine (% yes)	0.122	(0.328)	0.127	(0.334)	-0.005
Other Vaccine (% yes)	0.136	(0.343)	0.124	(0.33)	0.013
Use Curative Treatment (% yes)	0.133	(0.34)	0.089	(0.285)	0.044*
Dry Season Free grazing (% yes)	0.776	(0.418)	0.795	(0.404)	-0.02
Wet Season Free grazing (% yes)	0.361	(0.481)	0.402	(0.491)	-0.041
Observations	294		259		

Note: '***', '**', and '*' are significant at 1%, 5%, and 10% respectively

Table 38. Differences in marketing practices: entrepreneurs vs. traditional producers

	(1) Cattle (Market) Entrepreneurs		(2) Cattle (Saving) Traditional		Difference
	Mean	SD	Mean	SD	(1)-(2)
Sold to trader (% yes)	0.327	(0.47)	0.224	(0.418)	0.103***
Sold to other traders (% yes)	0.262	(0.026)	0.181	(0.023)	0.081***
Sold cattle inside village (% yes)	0.398	(0.49)	0.293	(0.456)	0.105***
Sold cattle outside village (% yes)	0.088	(0.284)	0.097	(0.296)	-0.009
Checked cattle price before sale (% yes)	0.347	(0.477)	0.29	(0.454)	0.057*
Check cattle price inside village (% yes)	0.2	(0.401)	0.193	(0.395)	0.007
Check cattle price outside village (% yes)	0.058	(0.233)	0.039	(0.193)	0.019
Check cattle price with traders (% yes)	0.153	(0.361)	0.104	(0.306)	0.049**
Don't know how to check price (% yes)	0.054	(0.227)	0.039	(0.193)	0.015
Pre-arrange price with trader (% yes)	0.167	(0.373)	0.143	(0.351)	0.024
Bargain price with trader (% yes)	0.303	(0.46)	0.231	(0.423)	0.072**
Observations	294		259		

Note: '***', '**', and '*' are significant at 1%, 5%, and 10% respectively

These univariate correlations are suggestive that cognitive capacity influences the decision to produce for the market. The results of Table 39 further suggest that this conclusion is robust to the effect of observed confounders as well as the effect of unobserved heterogeneity that shapes the decision to be a producer in the first place (using Heckman selection-correction).

Table 39: Explaining entrepreneurship

	Raise Cattle		Entrepreneur	
	Mean	SE	Mean	SE
Cognitive Planning	0.046	(0.040)	0.152***	(0.047)
Fluid intelligence	0.084	(0.061)	0.033	(0.057)
Inhibitory control (symmetric)	-0.053	(0.462)	1.097**	(0.466)
Working memory	-0.102	(0.075)	0.097*	(0.057)
Cognitive flexibility	0.089	(0.066)	0.124*	(0.067)
Attention (symmetric)	-0.010	(0.064)	0.180***	(0.059)

Note: '***', '**', and '*' are significant at 1%, 5%, and 10% respectively. Standard errors are clustered at the village level. We use the symmetric values of inhibitory control and attention so that higher values indicate better performance in the task. Additional confounders include demographic characteristics, village characteristics, district fixed effects. Excluded instruments used in estimating the participation decision include agro-ecological characteristics and the implementation of Land and Forest Allocation policy.

It is important to notice that there are no straightforward policy implications from this analysis. At best, this analysis suggests that training for market participation (a frequent component of many

current development programs in Lao PDR) would need to consider the underlying heterogeneity in terms of cognitive capacity of trainees.

7.7.3 Present bias predicts low-adoption of vaccination

Vaccines are an important component of any strategy to control (or eliminate) Foot-and-Mouth Disease (FMD), a highly contagious livestock disease that is endemic in much of mainland Southeast Asia, including Lao PDR. Given its costs, both in terms of lost productivity and constraints to trade (and, consequently, lower prices), much effort has been put into its control, both in terms of R&D (including by ACIAR) and on livestock health campaigns (for example, the SEACFMD campaign, with funding from Australia's DFAT). Despite a high Benefit Cost Ratio of 5.3 (Nampanya et al, 2018), vaccination against FMD is largely not adopted: in our sample of cattle producers interviewed in 2019, less than 30% vaccinated their animals against this disease in the previous 12 months.

A small literature has explained this puzzle of non-adoption of profitable vaccination by focusing on the importance of supply constraints (vaccine supply chain, including concerns about quality), or willing and capacity to pay (income, knowledge about the disease, transaction costs, and potentially gender of the decision-maker). Creed and Santos (2020) review this literature and note one important gap: almost no attention has been paid so far to the role of psychology, despite the increased recognition of its importance in vaccination decisions against human diseases. The analysis then addresses the importance of one behavioural bias that has received much attention in development economics – present-bias, the tendency of people to give stronger weight to payoffs that are closer to the present time when considering trade-offs between two future moments. Procrastination is a typical consequence of such preferences, particularly when upfront costs (monetary or otherwise) are present, as they receive a greater importance than future (more heavily discounted) net benefits.

Creed and Santos (2020) present the results of an econometric analysis of the decision to vaccinate as a function of the covariates typically examined in this literature and of measures of present-bias. Figure 14 presents the main results, expressed in standard deviations, which can be summarised in a relatively straightforward way: although several confounders typically used to explain this decision can in fact predict adoption of vaccination (namely, wealth and access to extension services), their importance is dwarfed by the much larger importance of present bias.

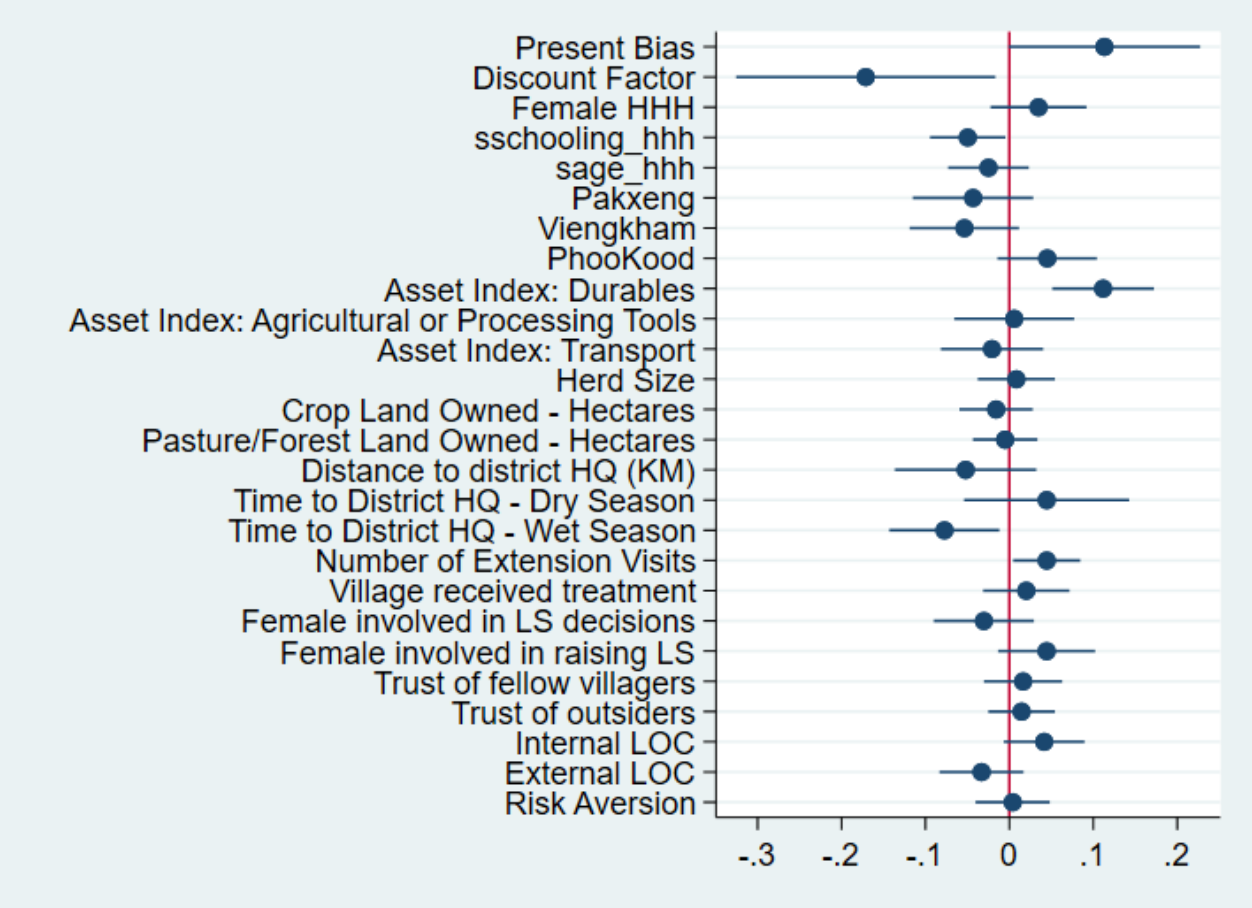


Figure XXX: Explaining the decision to vaccinate against FMD: the importance of present bias

Contrary to previous analyses, the policy implications are now relatively straightforward: a policy that accounts for such behavioural bias by changing the way that vaccination choices are made, by successfully lowering present costs of vaccination (time sensitive discounts, commitment devices, etc), should be expected to have a disproportionate positive effect on the adoption of this vaccine.

7.7.4 Future work

This line of work opens a variety of questions, of unequal interest in terms of directly driving policy changes. We list a few, on which work is ongoing or planned:

- Despite the shared language, psychologists and economists seem to use identical words with somewhat different meanings. Self-control is an obvious case: economists equate it with present-bias, while psychologists make little or no use of concepts such as time preferences (at least formally). Can the different concepts map into each other? (Huang and Santos, 2020).
- This lack of convergence in language is mirrored in terms of policy consequences: while economists have taken such behavioural biases as given, and propose changes in the way that policies are designed in order to account for them (nudges), psychologists have been less averse to suggest that cognitive capacity is effortfully malleable (ie, trained), even in adult age. Unfortunately, planned work with GIZ

exploring the feasibility of such training was not possible to be implemented in the context of this project, given time constraints.

- As it is perhaps clear from the language used, it is difficult to ascertain causality in the studied relations: sensitivity analysis seems to be the best that can be done in the absence of direct manipulation of cognitive capacity. In the absence of such manipulation, it seems fruitful to explore how other choices (eg, Buddhist meditation) impact on these traits (Santos, 2021).
- Finally, care has to be taken such that the results of this work are not used as a reheated discussion of the “deserving poor”: the behavioural biases analysed in the literature are clearly universal, although their consequences are likely much more important for those who have less resources to cope with their consequences.

8 Impacts

Section 7 presented and discussed all the results from this project. Here we present only a brief summary of what we consider to be the main impacts of the pilot interventions.

8.1 Scientific impacts – now and in 5 years

A large number of papers is currently under development, most focused on the results of the impact evaluations of the pilot interventions, while others go beyond the immediate needs of the project. Here we provide a summary of what we believe are the main scientific impacts of this project:

1) Quantifying the impact of conservation zones on biodiversity and mainstreaming impact evaluation into the activities of an International NGO: Butorac, Santos, Phouvin and Guegan (2020) present the results of a quasi-experimental evaluation of Fish Conservation Zones (FCZ), a popular and widely adopted management strategy of inland fisheries in Lao PDR. The study uses information from the Agricultural Census 2012 to construct the counterfactual to villages where FCZ were implemented by WWF-Laos as part of ComFish-III (by choosing villages outside the program that are observationally identical to those in the program). In addition to showing that FCZ did lead to improvements in biodiversity, this collaboration led to the incorporation of a rigorous evaluation of the impact of further conservation work (funded by the UK-Defra, through the Darwin Initiative, in Savannakhet).

2) Providing evidence to support policy: All pilot interventions were developed in close collaboration with officials from the Ministry of Agriculture and Forestry, benefiting from their understanding of the advantages of randomisation as a way to build a credible counterfactual. The evidence from the impact of these interventions is now submitted to different journals and under review (references in Section 7).

3) Developing a research agenda on the importance of incorporating behavioural economics in the analysis and design of agricultural development interventions: Meyer and Santos (2019) provide clear evidence that Socially Desirable Response (the tendency for respondent to provide answers that they believe may please the interviewer) is an important concern when relying on self-reported measures of outcomes (as most analysis relying on surveys do) that can be credibly corrected through additional data collection (in this case, of measures to engage in such behaviour). More generally, the project invested heavily in the collection of behavioural data, and the analysis of its importance to explain (or at least predict) seemingly “irrational” behaviour (such as the lack of adoption of profitable technologies, eg, cattle vaccination against foot-and-mouth disease).

8.2 Capacity impacts – now and in 5 years

The most important contribution to capacity building in both Australia and Lao PDR has been through the possibility to continue collaborative research on agricultural development in Lao PDR. The Lao researchers gained from exposure to the literature on impact evaluation and behavioural economics of which they were, until this project, relatively unaware. Some of these skills are now being applied during the PhD work on Ms Chitpasong Kousonsavath (PhD candidate, University of Adelaide) as well as in the plans for further studies of Mr Fue Yang. The Australian-based researchers gained via the opportunity to improve their knowledge on

constraints to agricultural development in the rapidly changing economic and political environment of Southeast Asia.

In addition, one PhD student, two Master students and one Honours student completed part of the requirements for their degrees through work on topics related with this project:

- Justin McKinley (Monash University, PhD student in Economics) used data from this project for the paper "Becoming an entrepreneur: cognitive function and the transition to the market" (chapter 2 of his PhD dissertation);
- Declan Butorac (Monash, Master of Environmental Management and Sustainability) submitted a thesis on "An evaluation of the impact of co-management of inland fisheries in Lao PDR";
- Roberta Rigo (Universita de Torino, Master in Economics and Statistics,; visiting student at Monash in 2018/19) submitted a thesis on "Design and feasibility analysis of an agricultural index insurance: the case of rice cultivation in Northern Laos";
- Christian Creed (Monash University, Honours in Economics) submitted his thesis on "Present bias predicts low adoption of profitable technologies: the case of livestock vaccination in northern Laos".

In addition, and as part of AARES 2020 (in Perth), the project conducted a pre-conference two-day workshop on impact evaluation, mostly directed at Early Career Researchers, which was very well attended. A second version of this same workshop, planned for Vientiane in May 2020 was cancelled due to travel restrictions.

Community impacts – now and in 5 years

Some information on impacts at community level during the life of the project was already provided in Section 7 of this report, and is summarised here. Future impacts will depend on the extent of their adoption, which are difficult to anticipate at this stage.

8.2.1 Economic impacts

The economic impact of the pilot interventions directed at reducing rice losses to rodents can be summarised by the associated Benefit-Cost Ratio. Both in the intervention implemented during dry season (competition) and in the wet season (training cooperation), these metrics are highly positive (in the most conservative estimates, the BCR are ~5 and ~10 for the competition and cooperation interventions, respectively) and encouraging regarding the potential interest in wider adoption.

The overall economic impact of promoting Demand Led Extension is more difficult to estimate, given the variety of outcomes associated with the decentralised demand for extension services. However, as we note, the economic benefits of reduction of cattle mortality alone are enough to cover the very modest cost of this intervention. Hence, in the most conservative case (ie, assuming no other benefits), the BCR would still be positive.

Future impacts depend on the extent of wider adoption of these interventions. There is ongoing work (funded by Monash University, via an internal grant) to promote the scaling up of the work on rodent control piloted during this project. If successful, we expect that it may lead to widespread benefits in many of the locations where rodent damage is most important. There are similar plans to promote the policy implications of the work on Demand Led Extension, although that additional work won't start until 2022.

8.2.2 Social impacts

The most significant social impact of the work conducted by this project is that it shows that communities can prioritise their needs in terms of extension. That was not a given, and it was recognised as a lesson learned by District officials. At more long term, we detect a significant impact of the work on Demand Led Extension on the willingness for communities to communicate with political authorities when local problems need to be solved, which we believe is a positive spillover from the work we piloted.

Finally, we note that we did not detect any increase in contribution to collective activities as a result of the work directed at training cooperation. This somewhat unexpected result suggests that the mechanisms at work (learning about others' willingness to cooperate) were interpreted quite literally, as applied to the problem at hand (rodent control). It is an open question whether longer term impacts will lead to an increase in cooperation in other domains.

8.2.3 Environmental impacts

There are two potential pathways to impact resulting from the work conducted in this project. The first builds on the similarity between Integrated Pest Management (IPM) and EBRM, which we promoted through our work on rodent control. Whether similar interventions are warranted likely depends on the extent of adoption of IPM and the feasibility of transposing the mechanisms we piloted (contest and training cooperation) to new contexts.

Secondly, and more general, a variety of environmental problems – from the management of invasive species to over-exploitation of the commons and the under-adoption of water and soil management technologies at watershed scale – have, at its root, the difficulty of coordinating the actions of affected agents. Our work shows that it may be possible to design relatively simple interventions, that either rely on small financial incentives or on new norms, to overcome such problems.

8.3 Communication and dissemination activities

The research team engaged in a variety of communication and dissemination activities, most of which were directed at the scientific community. They are too many to present an exhaustive list, but include the meetings of AARES (Australian Agricultural and Resource Economists Society), ACE (Australian Conference of Economists), EfD (Environment for Development), IEA (International Association of Economists), Econometric Society Asian Meeting (ESAM) and the Australasian Development Economics Workshop (ADEW), as well as academic seminars in a various universities.

In addition to public workshops and meetings with officials from the Ministry of Agriculture and Forestry, in Vientiane, Luang Prabang and Phonsavan, as well as in the four districts where we worked, team members engaged with the Research to Policy dialogue, promoted by ACIAR's office in Vientiane, on multiple occasions, and made several contributions to online fora dedicated to agricultural development in Lao PDR (LaoFab and Lao44).

However, most of the non-academic communication activities were planned for 2020, the last year of the project, when conclusions about the impact of the pilot interventions would be available. With the closure of borders, the difficulties in international travel, and the late adoption of webinars in Lao PDR, they were postponed. We expect to resume them in early 2022.

9 Conclusions and recommendations

9.1 Conclusions

Food security is a multifaceted concept, and the analysis of the drivers of food insecurity reflects its complexity. Particularly puzzling, in the context of Lao PDR, is the apparent lack of relation between growth and poverty reduction on one side and the persistence of food insecurity and malnutrition on the other.

It is this puzzle that motivated this research project, and led to the search for practical ways to reduce food insecurity. This search proceeded in two step. First, the analysis of existent consumption and health data, collected through nationally representative surveys, at household level (LECS and LSIS, respectively), complemented by the collection and analysis of own household data in two provinces (Luang Prabang and Xieng Khuang). This first step led to the following conclusions:

1) The microeconomic data supports a role for increased income in reducing food insecurity for households living in villages with access to year-round roads, but not for those households who lack access to such infrastructure and where, correspondingly, the importance of food insecurity assumes a much more pronounced seasonal aspect.

2) Factors such as shocks (droughts) or post-harvest losses (due to pests) are important determinants of food insecurity at household level.

3) Similarly, and even when accounting for household wealth, food insecurity seems to be driven by how decisions are made within the household (including women's agency) and behavioral constraints (including self-control).

These three conclusions guided the selection and definition of potential solutions to the constraints identified. In a second step, the project defined and evaluated the impact of those potential solutions. This step led to the following conclusions:

4) It seems feasible to reduce grain losses due to rodent damage, both pre- and post-harvest, by creating incentives that allow households to overcome the coordination problems at the root of the problem – either prizes (piloted during the dry season) or by training cooperation (piloted during the wet season). In both cases, the pilot interventions were, by design, low-cost and required little or no specialised human resources. The estimated BCR is, in both cases, fairly high, and preliminary investigation of willingness to pay for such interventions suggest that they are financially sustainable.

5) Devolving the decision about training priorities to communities, an example of community-driven development, seemed to be particularly effective in terms of promoting the adoption of new technologies among smallholders, an important element of broad-based economic growth. In addition, such initiative seems to have positive effects in terms of creating "social capital". Extension priorities naturally reflected the private economic opportunities in place in the region, largely focusing on the production and management of large livestock, with meaningful impacts in terms of adoption of technologies (vaccines, improved pasture).

6) Without substantial improvements in the design of insurance products, that may lower their cost, or large subsidies, it seems unlikely that index insurance against drought may be effective in reducing the importance of production shocks.

7) Cognitive capacity seems to predict a wide variety of behaviours that are of interest for policy makers focused on agricultural development, including the adoption of vaccines against foot-and-mouth disease, market orientation and marketing behaviour, and perceived vulnerability to food insecurity.

9.2 Recommendations

Avenues for development action

1) Post-harvest losses are frequently neglected, and without "champions" in the agricultural development bureaucracy, which frequently focus on increasing yields. Solutions piloted in this project and directed at rodent control are easily scalable, with minimal reliance on scarce trained human resources, and financially sustainable even in the absence of continuous outside funding.

R1: We recommend that the Government of Lao PDR includes the reduction of post-harvest losses (including, but not limited to, some of the approaches trialled in this project) as a central aspect of their food security strategy, particularly in communities with difficult access to markets, where seasonality in access to food is most important.

2) Without romanticising the idea of "community", this project showed that changing control of extension priorities (from district authorities to village committees) is plausibly one of the mechanisms underlying the wider adoption of training and of improved technologies, even when it is not accompanied by changes in the nature of trainers.

R2: We recommend that the Government of Lao PDR experiments with the devolution of such responsibility at a wider scale.

Supporting evidence-based development

3) Reducing child malnutrition (and stunting) is a central policy goal of the government of Lao PDR, and much hope is put in the potential role of agriculture in improving the nutrition status of rural households. Despite the existence of good quality data in the country, establishing a direct link between agricultural development and nutrition is made unnecessarily harder by the lack of a single survey that collects data on both consumption/poverty and anthropometric status/nutrition.

R3: We recommend that the Government of Lao PDR considers the inclusion of a module devoted to the measurement of anthropometric status of children in a future Laos Expenditure and Consumption Survey (LECS).

R4: In the absence of such data, we recommend that the Government of Lao PDR (and/or donors) consider the rigorous evaluation of the impact of activities such as LANN (Linking Agriculture with Nutrition and Natural resource management), which have been routinely included in development projects with the stated objective of linking agricultural development with nutrition outcomes.

4) Despite the large amounts of financial assistance to development projects, the evaluation of their impact is close to impossible, given limitations in terms of lack of clear identification of the counterfactual and generalised absence of baseline data. As a result, and despite the official interest in evidence based policy, it is impossible to discard bad ideas or to build on promising ones.

R5: We recommend that the Government of Lao PDR considers the development of a framework for the inclusion of rigorous evaluation of the impact of rural development programs,

which goes beyond their financial and/or physical execution, as an integral part of their definition and approval.

R6: We recommend that ACIAR considers a similar framework, particularly when R&D projects have a substantial development component.

5) Moving from promising research results (which are akin to a proof of concept) to impacts is likely to require continued support to dissemination at scale. Such task is likely to rely on research teams, as a first step, but necessarily transcends their comparative advantages in many aspects (training, communication, monitoring, among others).

R7: We recommend that ACIAR considers the development of a framework that supports the translation of research to impact, as a way to maximise the development potential of promising research results.

Further research directions

6) Market regulation in Lao PDR is routinely presented as a constraint to agricultural development, as it leads to large market power of the small number of legally authorised traders. This project provided some preliminary support for this statement in the case of large livestock (cattle and buffalo). It also identified some of the political economy constraints to changes, linked with the budgetary process at sub-national level.

R8: We recommend that ACIAR considers the support of further research into how feasibly liberalise livestock markets, given the potential importance of this sector for smallholders and the priority given to such trade.

One potentially fruitful direction for such research is to take advantage of the increasing availability of access to cheap information, fuelled by the diffusion of mobile phones. The IT revolution has already revolutionise access to savings and money transfers (eg, the introduction of mobile money), and is making increasing inroads in promoting the access of smallholders to urban markets (eg, through specially designed apps) or to extension services. That said, it is unlikely that they will overcome smallholders disadvantage in marketing without an explicit push for solutions that address their multiple constraints, which likely requires public funding.

7) Coordination failures may matter in many aspects of agricultural development, including the adoption of technologies that may be more effective when adopted at scale (eg, soil conservation, water management). One example, addressed in this project, is the case of Ecologically Based Rodent Management, an approach to rodent control (EBRM, developed during a long period of time, inclusive with ACIAR funding) which was routinely ignored because there were no mechanisms to the externalities at the root of coordination failures).

R9: We recommend that ACIAR considers the importance of such interdependencies, and whether there is room for research on innovative ways to overcome the difficulty in coordinate behaviour across smallholder farmers, particularly in cases where individual adoption is disappointingly low when contrasted with the promise of technological solutions.

Examples of situations where lack of coordination may play a role, not studied in this project, may include the adoption of Integrated Pest Management (with obvious similarities to EBRM), adoption of soil and water management technologies (that may only be individually profitable if adopted at scale) or the wider adoption of animal health practices (and the role of herd immunity).

8) Behavioural constraints seem to matter when explaining some of the heterogeneity of outcomes (perceived vulnerability to food insecurity) and adoption decisions (cattle vaccination, bargaining with traders). While it is important to avoid the trap of “blaming the poor for their condition”, it also seems important not to turn a blind eye to the evidence that suggests that

such constraints are potentially more harmful to the poor than to the rich. There exists by now a large literature that explores the impact of changes in choice architecture (aka, nudges) on a variety of outcomes (eg, inclusion of deadlines or upfront discounts as ways of limiting the negative impact of self-control on cattle vaccination).

R10: We recommend that ACIAR explores research opportunities that aim at designing policies that account for known behavioural biases and/or that explicitly incorporate the insights from acknowledging their importance in the design of new projects.

Although there is by now a list of possible interventions that may seem long, it is important to notice that it mostly builds on evidence from developed countries (through a variety of “Behavioral Insights Units”) and that they mostly focus on consumers’ behaviour in a relatively small set of markets (eg, formal savings). How to translate such lessons to households in developing countries, mostly reliant on seasonal income obtained as self-employed producers, is a largely unexplored area of research.

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10.2 List of publications produced by project

We list peer-reviewed publications only.

Roberta Rigo, Paulo Santos, Vito Frontuto (2022), Landscape heterogeneity, basis risk and the feasibility of index insurance: An analysis of rice in upland regions of Southeast Asia, Food Policy,Volume 108, 102237.

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