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Give a Man a Fishpond: Modeling the Impacts of Aquaculture in the Rural Economy

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ABSTRACT

The rapid growth of fish farming over the past three decades has generated heated debate over the role of aquaculture in rural development and poverty reduction. Central to these debates is the question of whether and how aquaculture impacts local incomes and employment, yet little empirical evidence exists on the issue. To address this question, we propose a Local Economy-wide Impact Evaluation (LEWIE) model which nests fish farm models within a general-equilibrium model of their local economy. The model is calibrated using primary data collected from 1102 households in Myanmar's main aquaculture zone, representative of 60% of the country's aquaculture farms. Using this model, we examine the impact of aquaculture on the incomes and labor market outcomes of fish farming households, but also crop farms and non-farm households in the cluster. Simulating one-acre increases in pond/plot surface we find that: (1) aquaculture generates much higher incomes per-acre than agriculture; (2) aquaculture generates larger income spillovers than agriculture for non-farm households by way of retail and labor markets; (3) small commercial fish farms generate greater spillovers than large fish farms. These results bolster the notion that fish-farming, and in particular small-scale commercial aquaculture, may have a significant role to play in rural development and poverty reduction.

> *"Give a woman a fish and you feed her for a day. Give her a fishpond, and you may generate income spillovers for the whole village."*

1. Introduction

Aquaculture (fish farming) has been the world's most rapidly growing food production subsector for the past three decades, and now generates more than half the fish destined for direct human consumption (FAO, 2016). The aquaculture sector's rise to global significance has seen an explosion of interest in its potential to stimulate economic growth and reduce poverty in developing countries, where most fish farming is concentrated. However, the literature lacks both a consistent theoretical framework and a compelling body of empirical evidence evaluating the contributions of aquaculture to rural economic development (Arthur, Béné, Leschen, & Little, 2013; Béné et al., 2016). This article's objective is to address this gap, using a rigorous empirically grounded evaluation methodology (Local Economy Wide Impact Evaluation) founded on a well-established body of economic literature (Filipski, Taylor, Thome, & Davis, 2015; Taylor and Filipski, 2014; Taylor, 2013; Thome, Filipski, Kagin, Taylor, & Davis, 2013), to estimate the economic impacts of aquaculture in a rural economy, including indirect impacts through input and factor markets.

Two main 'strands' are evident in the literature linking aquaculture with poverty reduction. We call the first the "small-scale" narrative. This emphasizes the direct benefits that resource-poor farming households may gain by producing fish for home consumption using simple low input technologies, and selling surplus to earn supplemental income. This narrative is present in the earliest work linking aquaculture and poverty (eg. Ahmed & Lorica, 2002; Edwards, 1999; Edwards, Little, & Demaine, 2002). It has been the dominant theme in the literature since this time (e.g. Bondad-Reantaso & Subasinghe, 2013) and continues to be widely espoused (eg. Golden et al., 2016).

We label the second strand the "SME" (Small and Medium Enterprise) narrative. This diverges from the small-scale narrative on two empirical observations: (1) aquaculture's rapid growth in

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Asia (and more recently Africa) has been driven overwhelmingly by the investments of commercially oriented farmers and supporting off-farm enterprises, employing a mix of capital intensive, productive, and increasingly sophisticated technologies (Belton & Little, 2011; Brummett, Gockowski, Pouomogne, & Muir, 2011; Hernandez, Belton, Reardon, Hu, & Ahmed, 2017; Belton, Bush, & Little, 2017); (2) the poorest households in communities where fish farming occurs rarely have sufficient resources to participate in aquaculture directly as producers, but are able to obtain benefit from the sector through employment linkages (Belton, Haque & Little, 2012).

Unlike the small-scale aquaculture literature, which emphasizes the direct benefits derived from small-scale, semi-subsistence fish farming by producers, the SME narrative infers that a large part of aquaculture's contribution to poverty reduction is indirect; resulting from business opportunities and employment created both on- and off-farm. Though not always explicitly framed in such terms, the SME narrative reflects the idea (well-established in agricultural and development economics), that rural growth linkages are a key mechanism by which poverty is reduced (Haggblade & Hazell, 1989; Mellor, 1986).

Growth linkages occur when growth in one segment of the economy generates spillovers to other segments via the interconnectedness of production, consumption, and employment markets, in what Dorward, Poole, Morrison, Kydd, and Urey (2003) refer to as a 'virtuous circle'. In the context of agriculture, spillovers happen when profits or wages earned from farming or related work are spent on productive investments or consumption. This creates demand for additional goods, services and labor, which in turn create further cascading demand for goods, services and labor.

For instance, farms often demand services and intermediate inputs produced by non-farm enterprises ('production linkages'). In addition to generating income for their owners, these enterprises can provide employment and income-earning opportunities for the poor (Haggblade & Hazell, 1989). Similarly, demand created when farm households or workers spend profits and incomes on consumption goods (food, clothing, transport, leisure activities, etc.) creates 'consumption linkages'. These linkages tend to strengthen as agricultural income grows (Haggblade, Hazell, & Dorosh, 2007).

Households operating small to medium-sized farms have favorable expenditure patterns for promoting growth in the local non-farm economy because they typically spend higher shares of incremental income gained on locally produced 'non-tradable' goods and labor-intensive services than large farms (Diao, Hazell, & Thurlow, 2010). Commercially oriented forms of aquaculture often require significant inputs of labor and other production inputs and are capable of generating much higher returns than staple crops such as rice (Belton, Ahmed, & Murshed-e-Jahan, 2015). Together, these facts suggest that small- and medium-scale commercial aquaculture has the potential to create denser rural growth linkages than either traditional crop agriculture or large scale aquaculture. This hypothesis informs all subsequent analysis in this paper.

A handful of previous studies have attempted to analyze indicators of the extent and size of production, consumption and employment linkages associated with aquaculture. Taken together, their results suggest the following points: (1) The indirect poverty impacts of aquaculture tend to be larger than the direct impacts (Belton, Haque, & Little, 2012; Kassam & Dorward, 2017); (2) Commercial aquaculture can create employment linkages that are greater than those associated with crop farming (Belton, Ahmed et al., 2015; Belton, Hein et al., 2017), and these employment linkages can be poverty and income inequality reducing (Irz, Stevenson, Tanoy, Villarante, & Morissens, 2007); (3) Small commercial fish farms may create larger multipliers of all types than small non-commercial or large commercial farms (Belton et al., 2012; Kassam & Dorward, 2017).[1]

However, the generalizability and comparability of results from these studies is limited by their deployment of varied methodologies, limitations in the size, representativeness and quality in the data utilized, the context specificity of the cases selected, and differences in the way in which growth linkages are conceived, evaluated or inferred. Béné et al. (2016) provide a similar critique of the broader literature linking aquaculture and poverty reduction. As Allison (2011) notes, "there is little direct quantitative evidence of the size of growth-multiplier effects from fisheries and aquaculture development" – this article provides some.

The present paper makes a methodological and empirical contribution to the literature by modelling production, consumption and employment linkages within the boundaries of a clearly defined rural economy[2] in Myanmar, using a large dataset (n = 1102) collected specifically for this purpose and statistically representative of nearly half of all aquaculture ponds in Myanmar (42%). We construct a local economy-wide impact evaluation (LEWIE) model of the areas surveyed, delineating how fish farms and crop farms interact with each other and with other local economic actors (Taylor, 2013; Thome et al., 2013). We use the model to perform simulations that evaluate the full economic contributions of crop farms, and fish farms of different sizes. This approach allows us to: (1) quantify growth linkages associated with aquaculture, and compare these with linkages created by crop agriculture; (2) analyze differences in the size and type of linkages created by small-scale and large-scale aquaculture farms, and; (3) assess shifts in income (in)equality associated with the growth of each of these activities.

By simulating a one-acre increase in the land (or pond) holdings of different types of household, we find that aquaculture: (1) produces higher overall incomes than agriculture on a per-acre basis; (2) generates higher income spillovers in the local economy. Fish ponds generate spillovers that are large relative to their direct impact (being of equal or slightly greater monetary value). We also find that small fish farms (defined as under 10 acres) generate higher spillovers than large fish farms (>10 acres), and that an increase in small fish farm area reduces local income inequality, while large farm growth raises inequality. These results highlight the importance of using an economy-wide lens when examining the role of fish-farms in rural development and poverty reduction, and resonate strongly with the SME narrative on aquaculture development.

The findings also contribute to ongoing policy debates in Myanmar. Myanmar's agricultural policy has historically favored the establishment of very large fish farms by granting land concessions. At the same time, strict regulations governing agricultural land use have slowed smallholder-led fish farm development. As a result, the majority of farm area and output in Myanmar is concentrated among large farms (Belton, Hein et al., 2017). Shifting policy priorities following Myanmar's democratization in 2016 mean that agricultural diversification beyond the staple rice is now encouraged, but restrictions on the conversion of agricultural

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[1] (Stanley 2003) presents evidence suggesting that export-oriented aquaculture may generate relatively small backward production linkages and large forward production linkages, though this is beyond the scope of our analysis in this paper.

[2] Although the aquaculture cluster is close to Yangon as the crow flies, and the existence of water transport links to the city play an important role in its location (Belton et al. 2017), it possesses few of the characteristics of commonly associated with *peri*-urban areas (Little and Bunting 2005). For example, research on which this paper is based showed that there is little in the way of mixed land use (agricultural, industrial, commercial, leisure) that characterizes the *peri*-urban zones surrounding most major Southeast Asian cities. In addition, infrastructure and connectivity is very limited; the average distance from surveyed villages to the nearest paved road is 3.1 miles, 68% of surveyed communities could not be reached by road during monsoon season, and 88% had no electricity connection.

land to fish ponds remain in place for now. Our finding that aquaculture creates much greater spillovers than crop farming, and that small-scale aquaculture creates more favorable spillovers than large-scale aquaculture, thus holds important implications for agricultural policy and the future of aquaculture development in Myanmar.

The remainder of the paper is organized as follows. The following section provides context on the characteristics of Myanmar's aquaculture sector. Section three describes the survey methodology, data and model specifications. Section four presents model results on the size and nature of growth linkages associated with large and small-scale commercial aquaculture and crop farming. Section five concludes by evaluating implications for the literature on aquaculture and poverty, and for agricultural policy in Myanmar.

2. Background: aquaculture in Myanmar

Aquaculture has grown rapidly in Myanmar over the last two decades and plays an increasingly important role in national fish supply (Belton, Hein et al., 2015). Fish farms are highly concentrated in the delta of the Ayeyarwady River, close to the former capital city of Yangon, where there are an estimated 235,000 acres of fish ponds (*ibid*).

Unusually for an Asian country, the ownership structure of fish farms in Myanmar is highly concentrated. Belton, Hein et al. (2017) estimate that half of all fish farms are sized under 10 acres, but that these make up only 4% of pond area. In contrast, farms of 100 acres and above account for 6% of farms, but 60% of pond area. Our own survey of fish farming households returns similar results.

The predominance of large fish farms is closely linked to Myanmar's agricultural land use policy history. From 1989, when the military government of the State Law and Order Restoration Council seized control of the country, large scale fish farming was promoted as part of a wider policy to encourage industrial-scale agriculture. Large areas of untitled land (including land previously worked by paddy farmers without formal tenure) were allocated to investors in what are now the main fish farming areas. The growth of small and medium fish farms has also been impeded, though not prevented, by land tenure regulations and policies intended to safeguard national self-sufficiency in rice production. These regulations mean that formal permission to convert agricultural land into ponds is difficult to obtain, and usually involves the payment of substantial bribes (Belton, Hein et al., 2015).

The tensions between: (1) state mandated use of land for smallholder paddy cultivation – the performance of which is among the worst in Asia, by any measure of productivity (World Bank, 2016); (2) state prohibition of smallholder conversion of paddy land into potentially higher return aquaculture, and; (3) state promotion of industrial scale fish farm development, form the crux of this paper in policy terms.

As Myanmar enters a new era of democratic government, calls for agricultural policy reform frame the promotion of smallholder-led agricultural diversification into high value crops (including fish) as a motor for rural growth (NESAC, 2016). However, these views are tempered in some quarters of government by a narrative that strongly equates food security with paddy production. The question of how competing uses of agricultural land perform in terms of local economy-wide impacts is thus one of critical practical relevance.

3. Data and methods

3.1. MAAS survey and data collection

All data used in this study originates from a household survey – the Myanmar Aquaculture-Agriculture Survey (MAAS) – implemented in May 2016. MAAS was designed to meet two objectives: (1) Generate a baseline of information on fish and paddy farm size structure, tenure status, crop management practices, yields, and profitability; (2) Quantify relative advantages of, and tradeoffs between, aquaculture and agriculture by estimating the size of spillovers in the local rural economy.

Aquaculture in Myanmar is heavily concentrated in three adjoining regions (Ayeyarwady, Yangon and Bago), home to 90% of the country's fish pond area (DOF, 2014). Most of these ponds are located close to the country's largest city (Yangon). A two-stage sampling procedure was adopted to gather data from groups of village tracts with high concentrations of fish farms.[3]

For first stage sampling, satellite images from Google Earth were analyzed to pinpoint all inland fish ponds in Ayeyarwady, Yangon and Bago. Ponds were identified through a systematic manual search of high resolution images and tagged digitally to generate a database of pond boundaries and locations. After cross-checking for validation, ponds retained in the database were mapped using Arc-GIS software. The identified ponds are shown in Fig. 1. Pond area and density (pond area divided by total land area) were estimated using Arc-GIS in every village tract where ponds were identified. The 25 village tracts estimated to have the highest densities of ponds were selected for survey. These village tracts were spread across four townships within a 60 km radius of Yangon. Together, they form what we refer to as the aquaculture cluster, depicted in Fig. 1. Overall, the village tracts selected for survey contained 42% of the total area of inland fish ponds in the country.[4]

For second stage sampling, enumeration areas (EAs) were selected from the 25 aquaculture cluster village tracts by probability proportional to size, using the national population census of 2014 as the sampling frame. This procedure yielded a sample of 49 EAs. A census of households was conducted in every selected EA to serve as the final sample frame for randomized selection of respondent households.

The sample was designed to represent the entire population of the aquaculture cluster, including fish farming, crop farming and landless households, to facilitate estimation of spillovers from aquaculture and agriculture. Eight fish farming households and seven non-fish farming households were interviewed in each EA. Non-fish farming households included both crop farmers and those engaged exclusively in off-farm employment. Households operating fish farms of 40 acres or more were selected with 100% probability to ensure a sufficient sample to support statistically valid analysis. Survey weights were applied during analysis to correct for the effects of the sample design.

Respondents from 685 households in the aquaculture cluster village tracts, representing a total population of about 29,087 households, were interviewed one on one in the privacy of their own homes. A total of 242 fish farming households were surveyed. These included 151 growout farms producing food fish for sale and 73 specialized nurseries producing juvenile fish “fingerlings” for sale to growout farms. In addition, 113 crop farming households and 347 non-farm (landless) households were surveyed within the cluster.[5]

A three-part survey instrument was fielded, comprised of:

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[3] Village tracts are the smallest administrative units in rural Myanmar, usually comprised of around 10 villages.

[4] Specifically, the three regions Ayeyarwady, Yangon and Bago contain 90% of all aquaculture pond in the country, and the selected village tracts are home to 47% of the ponds in these three regions.

[5] The full MAAS survey also includes an “agriculture cluster”, featuring an additional 15 village tracts, 29 enumeration areas, and 417 households. In total, the full dataset has 1,102 households, representative of 37,390 households. Only the aquaculture cluster economy was modeled for this article.

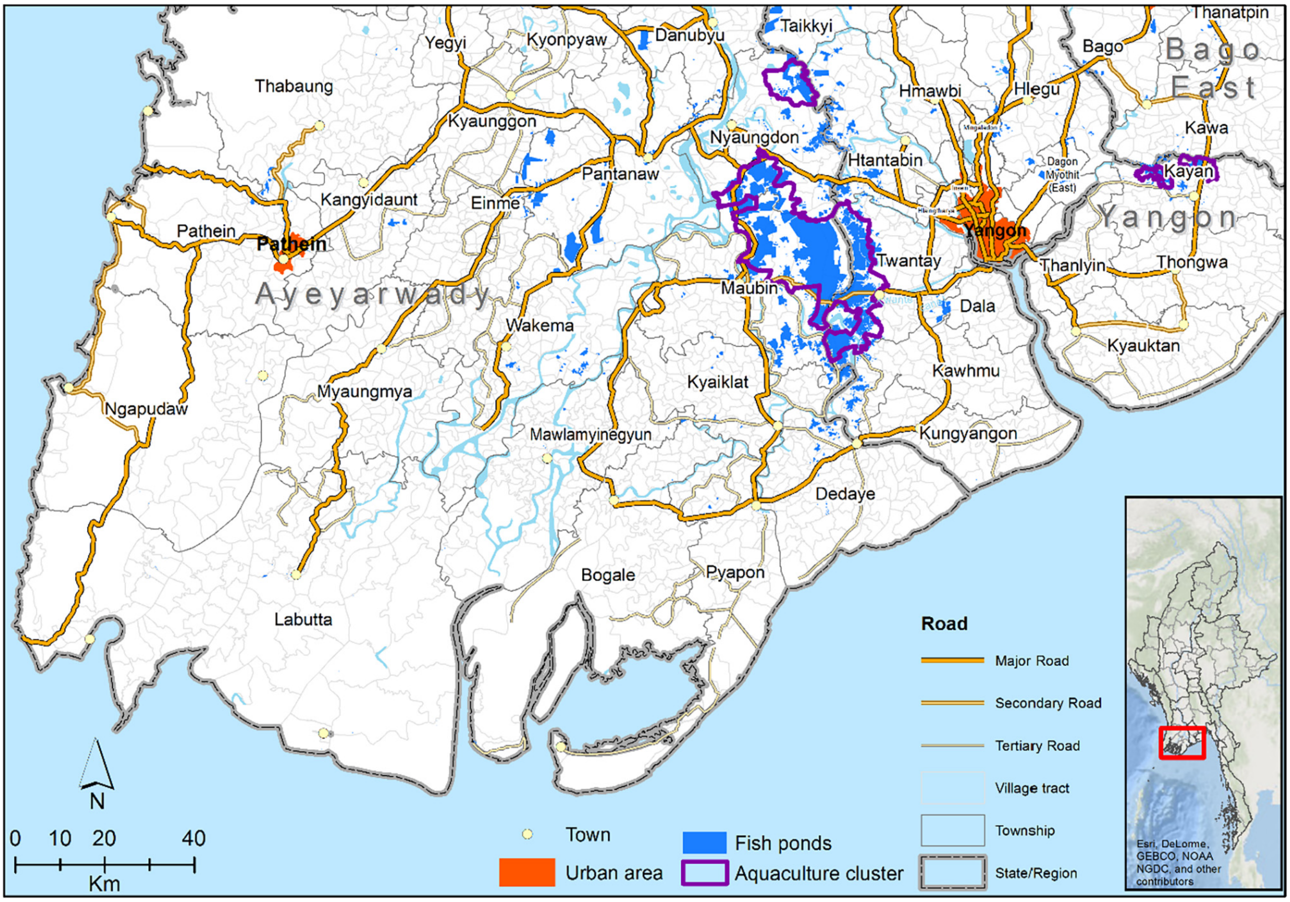

Fig. 1. Location of Ponds and Surveyed Aquaculture Village Tracts.

1) A *household* section, containing modules on household composition, off-farm employment, land and asset ownership, and consumption. This was administered to all households.
2) An *aquaculture* section, administered to all households operating fish "growout" farms or specialized nurseries. The instrument included modules on pond holdings and tenure; quantities and costs of inputs used (including labor), and the quantity and value of fish produced. Separate questionnaire modules were used to collect production data from growout farms and nurseries, in recognition of differences in the production logics of the two activities.
3) An *agriculture* section, divided into two sub-sections on monsoon season and dry season field crop cultivation, and incorporating modules capturing data on landholdings, input application and costs (including labor), and crop yields, sales values and marketing practices.

3.2. Sample characteristics

This subsection presents some basic descriptive statistics from MAAS on the agrarian structure of the aquaculture cluster and selected aspects of fish farming, crop production and labor therein. This information provides context for the interpretation of modelling results presented later in the text. More information can be found in Belton, Filipski et al. (2017).

Levels of landlessness in aquaculture cluster villages are high, at 70%. Twenty percent of households are primarily engaged in crop farming and 10% practice aquaculture. Of this latter group, one quarter also possess agricultural land. The large share of the population dependent entirely upon off-farm employment means that spillovers generated by agriculture and aquaculture play a particularly important role in determining the welfare of households in the cluster.

Two types of fish farm were surveyed: (1) specialized nurseries, (growing juvenile fish "fingerlings" for sale to growout farms)[6], comprising 41% of fish-farms; (2) "growout" farms producing food fish for the market (59% of fish-farms). Among growout farms, 51% were 10 acres or less in size. For the purposes of this paper we define these as small fish farms[7]. The 49% of growout farms of more than 10 acres were defined as large. Households operating fish growout farms own more than three times more land than crop farming households. The average crop farming household owns 9.8 acres of land (median 6.1). Households operating growout ponds own an average of 29 acres of land (median 10 acres). Specialized fish nurseries are much smaller (mean 3.7 acres, median 1.7 acres). The all-household average area of land owned (including households without agricultural land) is 4.2 acres, with a median of just 0.16 reflecting very high levels of landlessness.

Fish production and crop farming are both highly commercially oriented. More than three quarters of the paddy crop, and almost all of the pulses (mainly green gram and black gram) produced in the study area were sold. Although 93% of growout farms reported consuming some of the fish they harvested, either directly

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[6] Hatcheries and any nursing facilities associated with them were considered out of scope for the survey. The high ratio of nurseries to growout ponds reflects the high average size of the latter (and, consequently, their high demand for nursed seed). This creates opportunities for large numbers of small nurseries

[7] The choice of 10 acres as the upper cut-off for small-scale fish farms was intended to reflect the structure of landholdings in the area studied, corresponding with median fish farm area, and mean crop farm area.

or as gratuities to workers, the quantities consumed represented less than 1% of total production among large and small farms alike. Farms referred to here as 'small' are therefore similar to the small and medium commercial farms that feature in the "SME narrative" (outlined above), rather than the 'traditional' semi-subsistence farms that populate the "small-scale" narrative.

Fish growout farms specialize primarily in the production of carp species, the most important of which are rohu, catla and mrigal (stocked by 94%, 74% and 60% of farms respectively)[8]. Nursery farms specialize mainly in nursing these same species. Many large farms vertically integrate nursing functions, but the market for seed is vibrant: two thirds of all growout farms obtain at least some of their fingerlings from off-farm. This share rises to 85% for small growout farms. Almost all fish seed produced by specialized nurseries is sold to growout farms located in the aquaculture cluster. Fish seed nursing is thus a locally important backward production linkage.

Much land in the aquaculture cluster is low lying and vulnerable to heavy flooding during the monsoon. As a result, fifty-eight percent of crop farms there are limited to production of a single irrigated dry season rice crop. Thirty-three percent of farms produce a monsoon paddy crop, followed by a dry season crop of pulses (mainly black gram, with some green gram). The average annual return per acre of agricultural land (all crops) in aquaculture cluster villages is 1.6 times lower than in nearby villages where no aquaculture takes place. This reflects the low average productivity of agriculture in the low lying, flood-prone villages of the aquaculture cluster, where only 36% of farms produce two crops per year, as opposed to 79% in non-fish farming villages.

Average returns from aquaculture are 4.7 times higher than returns from agriculture in fish farming villages. The average gross margin earned by fish growout farms is $646/acre. Nurseries generate similar returns ($681). Incomes from fish-farming are highly variable (the median for growout farms is $333/acre, about half of the mean). However, this still lies well above the average gross margins for monsoon paddy, dry season paddy and black gram ($85/acre, $128/acre and $174/acre, respectively). The all farm average annual gross margin is $153/acre.

Differences in profitability and scale among different types of farm are reflected in consumption expenditures (a proxy for income). Members of households that operate fish growout farms have an average annual consumption expenditure of $1525 per capita. For members of nursery farming households, the figure is $971. The average for households not engaged in aquaculture (crop farming plus non-farm) is $689. This gap suggests that fish farming households may generate larger consumption linkages than non-aquaculture households, provided that they spend part of this income on locally produced 'non-tradables'.

Fish farms generate demand for almost four times more person days of labor (unpaid family labor, plus hired casual labor and hired long-term labor) per acre/year than crop farms (94 days versus 24 days, respectively, on average). Low demand for labor in agriculture relative to aquaculture reflects the highly seasonal nature of the former. For example, jobs like weeding field crops are performed only occasionally, whereas tasks such as feeding and guarding fish must be performed daily throughout the production cycle, which averages close to one year in duration. Agriculture's low demand for labor also reflects high levels of agricultural mechanization, and the widespread use of other labor saving practices such as broadcasting paddy seed.

Among fish growout farms, those under ten acres generate by far the greatest relative demand for labor (152 days/acre/year). Large fish farms generate an average demand for labor of 32 days per acre/year. Differences in labor demand from large and small farms likely reflect economies of scale for certain types of labor (e.g. the number of person hours required to guard a 20-acre pond may differ little from the number required to guard a 5-acre pond). Conversely, large, well-resourced farms are more likely to invest in capital intensive labor saving technology, both for pond construction and maintenance (mechanical backhoes) and pond operation (e.g. water pumps, boats). As shown later, differences in employment multiplier effects among crop agriculture and small scale and large scale fish farming have very significant implications for the magnitude and distribution of spillovers generated.

3.3. LEWIE modeling

3.3.1. Background

Local Economy-wide Impact Evaluation (LEWIE) modeling was developed to reflect the fact that local economies, like national or regional economies, function by way of interconnected markets (Taylor & Filipski, 2014; Taylor, 2013). At the local scale, the prices of certain goods, services, and factors can be influenced by local supply and demand conditions. Typically, the price of items that are not easily traded outside of the local economy (such as land, local services or, to a lesser extent, labor) will be more responsive to local market conditions than items for which markets are seamlessly integrated at the national or international level (Abdulai, 2006; Fackler & Goodwin, 2001). In our case, rice and locally-produced fish are both sold almost entirely through Yangon, such that local demand in the cluster has virtually no bearing on sales prices.

The other insight central to LEWIE modeling is the fact that rural households participate in local markets both as producers and consumers of goods and services, and as providers and users of factors. For example, while rural households may benefit from higher prices of grain as producers, they will lose as consumers. Similarly, households will gain from higher wages if they work outside their own household, but they also need to increase pay for workers hired on their own farms.

In view of these considerations, the core elements of LEWIE are agricultural household models (Singh, Squire, & Strauss, 1986), which capture the dual nature of farm households with their production and consumption behavior. LEWIE nests several of these models into an economy-wide model, reflecting the way households trade amongst themselves in the local economy, as well as with the outside economy (Taylor & Filipski, 2014).

LEWIE models have been used to evaluate local economy-wide impacts of anything from cash transfers (Filipski et al., 2015; Thome et al., 2013), irrigation investments (Filipski et al., 2013), refugee settlements (Taylor et al., 2016), or price volatility (Filipski, Aboudrare, Lybbert, & Taylor, 2017). Using LEWIE to study the impacts of aquaculture development represents not only a novel application of the methodology, it also requires adapting the model to accommodate simulations based on land expansion or conversion between different uses.

3.3.2. In practice

Mathematically, LEWIE models are structural general-equilibrium (GE) models, rooted in the Computable General Equilibrium (CGE) tradition (Löfgren, Robinson, & Harris, 2002). They are systems of equations that represent both the production side and the consumption side of all markets in the economy (appropriately aggregated), and the prices and trade volumes that make those markets clear. The full model statement is available in Appendix A. In general terms, the system is composed of three major blocks of equations: the production block specifies how households combine factors and inputs to generate production

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[8] Small farms are slightly more likely to stock non-carp species such as tilapia, pacu and freshwater prawn, but the difference in stocking practices across farms of different sizes is not great.

output, the consumption block specifies how much income households have and how they spend it, and the market clearing block specifies how supply meets demand and at what price. More specifically, the model functions as follows.

All households in the economy are categorized into one of several groups (in our case, six). Similarly, all goods (and services) in the economy are categorized into one of several goods (in our case, seven). In the model, goods can be produced locally (by the households) or purchased from the outside ("imports" into the local economy). Households who produce the goods do so by combining factors of production such as land, labor (family or hired), purchased inputs such as fertilizer or feed, and intermediate inputs coming from other production activities. Factors are combined following a Cobb-Douglas production function (fixed factor shares), but intermediate inputs follow a Leontief schedule (fixed relative quantities) (Leontief, 1986). Thus, the relative amounts of factors used in production are determined by their relative prices.[9]

The households that own factors used in production are compensated in the form of income, which they can use to purchase goods. These purchases are represented by a Cobb-Douglas consumption function, meaning that households spend their income per fixed value shares.[10] Household savings and investments are treated the same way as goods, and represent a fixed share of income. Since we run the model over a one-year period, amounts saved or invested do not impact production.[11]

Prices in the economy are determined either by the interaction of local supply and demand (for "non-tradable" goods, meaning not traded outside of the economy), or determined exogenously (for "tradable" goods). Whether they are tradable or not, all goods must satisfy market-clearing equations, which complete the model. These equations guarantee that, for each good or factor, the total sum of amounts supplied (produced, imported or initially endowed) are accounted for somewhere on the demand side (for consumption, export, or use in production). Because the model is based on households, the same equations exist at the household level: the sum of all endowments, purchases, or production in the household must match total consumption, sales, or use in production.

The choice of how to distinguish household groups, goods and factors in a LEWIE model is guided by the specific research questions one hopes to answer through simulations. Given our focus on aquaculture and farm size, in this application we distinguish five groups: three fish-farming groups (small-scale, large-scale, and nurseries), crop farmers, and non-farm households. Each household in the dataset is mapped to one of these five groups. The same is true for activities, goods, and factors in the model. All accounts in the model can be seen in Table 1.

One of the strengths of these types of model is that they accommodate a wide variety of "market closure assumptions", or rules by which the modeler chooses to depict how a good or factor is traded. In this case, as can be seen in Table 1, we consider land and capital to be fixed in production, for each activity and each household (this is a common short-term assumption). Labor is only traded within the village (another common short-term assumption), but its supply is highly elastic (meaning that we assume that there exists unemployed or underemployed labor in the economy).[12] Purchased inputs are tradable goods, purchased at a fixed price from outside traders. Crops and fish are sold at fixed prices, determined outside of the economy. Retail goods are purchased at a fixed price from outside traders, but the markup imposed by local retailers is endogenous and responds to local demand.

3.4. Model calibration

3.4.1. Calibration process

Calibrating LEWIE models requires estimating all production, consumption, and trade flows in the local economy. Those data are usually calibrated from household surveys, such as Living Standards Measurement Surveys (LSMS). Average values of production and consumption are computed for each type of household. To accurately represent the full economy, these averages are then multiplied by a weighted number of observations, appropriately accounting for sampling bias. Econometric estimates of production and consumption functions provide the factor value shares and expenditure shares. This allows us to compute all the amounts consumed or produced by each household type.

In addition to production and consumption estimates, this economywide picture needs to define flows of goods into and out of the economy. For each item mentioned in the production, consumption, or business sections of the questionnaire, respondents were asked where it was purchased or sold.[13] We rely on these provenance and destination questions to determine what fraction of production inputs are coming from the local economy (within the village tract or a neighboring village tract) and what fraction are coming from external sources (urban areas or rural areas of other townships). Finally, we use the net balances of local supply and demand to determine trade with the "rest of the world", including trade in commodities and exogenous household incomes. This completes calibration and yields the picture of a balanced economy: one where incomes and outlays are equal for each account.

3.4.2. Monte-Carlo validation procedure

Simulation methods do not offer the possibility to assess the significance of results through statistical hypothesis testing. However, because we econometrically estimate many of the parameters used in calibration, we can exploit these estimations to provide an additional measure of confidence for our results, using a "Monte-Carlo" approach (Robert & Casella, 2005). For each parameter estimated econometrically, we assume it follows a normal distribution characterized by the point estimate and standard error from our regression tables. Instead of using the point estimate as our parameter, we can use any random draw from that distribution. We do this repeatedly N times, simultaneously drawing all parameters at random from their respective distributions, and calibrating the model N times, once with each set of drawn parameters. We then run the simulations N times, obtaining a different result every

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[9] Fish will grow even in the absence of feed inputs, because sunlight supports the growth of plankton and algae which provide a source of nutrients. As such, fish feed should be thought of as a substitutable input bringing diminishing returns to scale, and can be modeled with a Cobb-Douglas schedule.

[10] The model equations in the appendix are specified as a linear expenditure system (Stone-Geary) for the sake of generality, but in the absence of consumption minima they effectively collapse to Cobb-Douglas form.

[11] When running the model over multiple periods, savings and investments can used to update production parameters and simulate dynamic growth – but we do not apply these techniques in this paper.

[12] This assumption does not drive results. Some indications that the rural labor market in Myanmar is tightening exist, but unfortunately no elasticity estimates are available. The results presented in the paper were performed with labor supply elasticity equal to 100 (highly elastic), but repeating simulations with labor supply elasticity set to 1 (moderately elastic) or to 0.1 (inelastic) does not alter results in any substantive way, and leads to the same conclusions. In addition, since the elasticity assumption is common to all simulations, it has no bearing on the relative comparisons.

[13] Such questions are not standard for LSMS-type surveys, and constitute one of the prerequisites for running a LEWIE analysis. For purchased inputs and consumer goods respondents were asked "From where did you get [item]? a) This village, b) This village tract, c) Neighboring village tract, d) Nearest town, e) Yangon City, f) Other township (specify), g) Other region (specify)". The corresponding questions are asked about items sold in the production and business sections. Specifically, we considered answers a) b) and c) to be local-economy transactions, and all other answers to be "rest-of-world" transactions.

Table 1
Accounts in the LEWIE model.

Code	Description	Number of observations (weighted percent of households)
Households		
FSm	Small fish farmers (<10 acres)	64 (3%)
FLg	Large fish farmers (≥10 acres)	95 (3%)
Nurs	Fish nurseries (without growout ponds)	66 (3%)
Ag	Crop farmers (without ponds)	113 (20%)
LL	Landless households (all non-farm)	347 (71%)
Activities	*Description*	*Households Participating*
Crop	Crop production	All landed households (FSm, Flg, Nurs, Ag)
Fish	Fish farming	Small and large growout farms (FSm, FLg)
Fseed	Fish nursery farming	All fish farms (FSm, FLg, Nurs)
Prod	Other local production (ex: crafts)	All households
Ret	Retail	All households
Ser	Services	All households
Commodities	*Description*	*Market Assumption*
Crop	Locally produced crops (mostly grain)	Tradable (exogenous price)
Fish	Locally produced fish	Tradable (exogenous price)
Fseed	Fish seed	Non-tradable (local price)
Meat	Meat	Tradable (exogenous price)
Prod	Other locally produced goods	Tradable (exogenous price)
Ret	Locally purchased retail goods	Non-tradable (local price)
Ser	Locally provided services	Non-tradable (local price)
Out	Goods and services purchased outside of the cluster	Tradable (exogenous price)
Factors	*Description*	*Market assumption*
Land	Land	Fixed in production
Labor	Labor	Non-tradable but highly elastic supply
Capital	Capital	Fixed in production
Input	Commercial input (fertilizer, fish feed, etc.)	Tradable (exogenous price)

time. The variability in those results reflects the precision of our parameter estimations: imprecisely estimated parameters will produce more variability in the results. At the end of the procedure, we report not the result of one run of the model, but rather the mean value of all N results. This also allows us to report the standard deviation around that mean value, thus conveying a measure of precision with what are called "Monte-Carlo confidence bounds". This procedure expands and streamlines sensitivity analysis, and is another salient feature of this work.

In this application, we were able to econometrically estimate all factor shares, while consumption expenditures were computed directly due to lack of data. Parameters estimated econometrically were drawn from their estimated distribution as described above, while parameters computed directly were assigned a 10% error in the Monte-Carlo exercise – similarly to what is done in standard sensitivity analysis. We set N = 200, which was large enough to obtain stable results.[14]

3.4.3. Production and consumption parameters

We present the value shares of factors and intermediate inputs used in fish and crop production in Table 2 (other activities in Appendix). Factors are production inputs that produce value added: land, labor, capital, and commercial inputs into production (feed, fertilizer). Intermediate inputs are seed and operating costs (taxes, financing, transportation costs, etc.). Intermediate inputs are treated differently in the production function because they must be added in fixed proportion and cannot be substituted for one-another.[15] Value-added shares were computed by regressing the total value of output (logged) on total value or quantity of land, labor, capital, and commercial inputs (also logged).[16]

The top part of the table presents the value-added production coefficients: they can be interpreted as shares of the total value added component of production. They were computed by drawing from truncated normal distributions based on the point estimate and standard error from log-log regresions of production value on input values, then rescaling to ensure they add up to 100 percent (the results of the log-log regressions are presented in the Appendix). The bottom part of the table presents intermediate input shares. These were computed directly as the value of those expenses over total output value.[17]

Comparing production functions between different households yields several insights. First, and most importantly, small fish farms tend use less feed inputs and capital than large farmers. Instead, their production function is relatively more labor- and land-intensive. This insight is key for the remainder of the analysis, as it explains why smallholders may generate more economic activity locally than their larger counterparts. The bottom part of the table suggests that fish farming requires more intermediate inputs than crop farming. As a fresh product, fish require much higher operating costs at harvest time (ice, transport). Aquaculture farms also often operate using informal loans and have much higher financial costs than agriculture, which is financed in part by government subsidized crop loans. Seed accounts for a similar share of costs for fish growout farms and crop farms, but a much higher share for fish nurseries. These purchase large quantities of hatchlings, but require low feed inputs relative to growout farms.

Table 3 shows expenditure shares for all household types in the model. Due to incomplete data, these could not be estimated econometrically, but rather were obtained by aggregating all expenditures within household groups and computing the share devoted to each category. Overall, the households display relatively similar expenditure patterns. It is notable, however, that large fish farmers (which are on average wealthier) spend a far greater share of their income (43%) outside of the economy than other types of

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[14] Using too few repetitions leaves the model vulnerable to outliers, but we found that a few dozen repetitions were sufficient to obtain stable results.

[15] For instance, a small field that was plowed can yield the same output as a large unplowed field (labor substitutes for land area). However, neither field yields anything without seeds, no matter how large or how much it gets plowed (land and labor cannot substitute for seeds).

[16] The log–log regression is consistent with a Cobb-Douglas production function.

[17] Fixed proportion intermediate inputs are consistent with a Leontieff production function.

Table 2
Production function parameters for agriculture and aquaculture.

Value shares of total output		Small fish farms (Up to 10 acres)	Large fish farms (>10 acres)	Fish Nurseries	Crop farms
Factor shares	Land (or pond)	25%	23%	11%	18%
	Labor	13%	7%	5%	9%
	Capital	2%	6%	14%	23%
	Production inputs (incl. feed, fertilizer)	39%	50%	24%	40%
Intermediate input shares	Seed (fish or crop)	9%	8%	30%	9%
	Other expenses and operating costs	12%	7%	15%	1%
Total		100%	100%	100%	100%

Source: Author estimations.
Notes: Factors create value added (top 4 lines) and get combined in a Cobb-Douglas function (fixed value shares), while intermediate inputs requirements follow a Leontief function (fixed proportions). Production parameters for remaining activities (retail, services, etc.) are provided in the appendix.

Table 3
Consumption shares of income for households in the model.

Goods or services	Small fish farms	Large fish farms	Nursery farms	Crop farms	Non-Farm
Crops	16%	6%	11%	18%	19%
Meat	11%	5%	9%	10%	11%
Fish	5%	3%	4%	5%	6%
Other local production	3%	5%	3%	2%	7%
Local retail	22%	27%	29%	39%	28%
Local services	14%	12%	14%	9%	8%
Outside purchases	30%	43%	30%	16%	21%

Source: Author estimations based on aggregate expenditures of households in the model.

household. In local economy-wide terms, such expenditures are equivalent to “leakages” out of the local economy, and do not generate spillovers – large fish farm households will likely generate smaller multipliers through the expenditure channel.

Once calibrated, the model is at equilibrium, meaning that the values we chose for variables and parameters constitute a solution to the system of equations that is the model. Simulations are then performed by changing specific parameters of the model and running an algorithm to find the new variable values that constitute a solution. In what follows, all our simulations will be based on exogenously changing the value of land assets of given households. The new model solution then tells us how market balances in the economy are likely to adapt in response to such an event.

3.5. Simulation design

We use the model to simulate five scenarios, with the goal of informing two comparisons: first, to compare fish farming to crop farming; second, to draw out differences between smallholder and large-holder aquaculture. The five scenarios are outlined in Table 4.

Simulation 1 is a hypothetical scenario by which a previously unused acre of pond is allocated to a small fish farmer (which we will call the “recipient household” in each simulation). This is akin, for instance, to land distribution or reallocation, from unused public land to private pond. The pond is assumed to be free, to have been excavated already, and to be ready for production. It is not taken away from another household, nor does it reduce the total area of arable land in the economy. These simplifications are intentional. Purchasing the pond would likely entail a payment to the previous owner, with all the associated spillovers. Excavating ponds has traditionally been done manually using local laborers, which would also generate employment and income spillovers (though this channel is gradually diminishing in importance, as fish farmers increasingly hire mechanical backhoes from outside of the cluster to do the excavation). The related payments to previous owners or workers would obscure the simulation results and make it harder to trace impacts through the model. Simple simulations allow us to isolate the interlinked impacts of increasing operated pond area, and facilitate comparison between scenarios.[18]

In modeling terms, simulation 1 is carried out by exogenously increasing the value of pond assets held by the small fish farmer group (SFF) by $166 (MMK 200,000), the average per-acre rental rate for fish ponds reported in the MAAS survey.[19] All the farmers in each group are represented in aggregation by one representative household. This simulation can thus be interpreted as an average small farmer receiving a free acre of pond.

Simulation 2 is exactly the same as simulation 1, but the recipient of the free pond is the second household group, large fish farmers (LFF). Again, the simulation entails exogenously increasing the value of their pond assets by the rental rate of $166. Simulation 3 is quite similar again, but this time it is the crop farmer group (CF) that receives a free acre of land. In that case, the value of the acre is $58 (MMK 70,000), reflecting the lower rental-rate on crop land as opposed to ponds.

The model fixes land inputs in the simulations, such that the household receiving the acre of land (or pond) will not leave it fallow nor resell it to another household, but rather will put that land into production. This means that in simulation 1, the small fish farmer household will adapt the quantity of inputs it uses (fish seed, labor, etc.) to reflect its increased pond area. This will affect the quantity of fish it produces and the income it generates from fish farming. It will also affect the local demand for inputs, and thus indirectly impact any other household that either provides or purchases those inputs. These updated incentives lead the other households to adapt their behavior, which in turn also affects local market demand, prices, and all households participating in these

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[18] In addition, an important cost of putting a previously unused acre of land into production might exist if that land had value for local inhabitants as a common property resource, for instance as a source of firewood or wild fish. However, since the cost of losing access to that resource would be identical in all three simulations it makes sense to assume it away when comparing these scenarios – which is not to minimize the importance of such costs.

[19] Conversion rate used throughout the paper: MMK 1200 = USD $1.

Table 4
Simulation scenarios and parameters.

	Scenarios:One previously unused acre of land is put into production			Scenarios: One acre switches from agricultural use to aquaculture use	
Simulation	Sim 1	Sim 2	Sim 3	Sim 4	Sim 5
Description:	Give **small** fish-farmer one additional acre of fishpond	Give **large** fish-farmer one additional acre of fishpond	Give **crop** farmer one additional acre of crop land	Let **small** fish-farmer convert one additional acre from crop to fishpond	Let **large** fish-farmer convert one additional acre from crop to fishpond
Change in value of pond assets	USD 166	USD 166	–	USD 166	USD 166
Change in value of cropland assets	–	–	USD 58	USD-58	USD-58

markets. The model helps trace these effects rippling through the local economy.

Simulations 4 and 5 are similar to simulations 1, 2, and 3, but involve a trade-off. In simulations 4 and 5, we let the recipient household convert one acre of land from crop farming to fish farming. In practice, this means that we increase pond assets by the value of a 1 acre pond, and at the same time reduce cropland assets by the value of a 1 acre piece of crop land. We do this for the small fish farmer in simulation 4, and for the large fish farmer in simulation 5.[20] Again, we limit the complexity of the simulation by assuming that the converted land does not change hands, and that the digging of the pond is costless.[21] Comparing simulations 1 through 5 allows us to highlight how differences in the production parameters between small fish farms, large fish farm, and crop farms, translate into differentiated local economy-wide impacts.

3.6. Measuring inequality

The LEWIE portrays all households in the cluster grouped into land- and pond-ownership categories. This makes it possible to measure income disparities between them, and how those disparities change in the simulations. We measure inequality with the Theil index, which is a special case of the general entropy index and a commonly used statistic for measuring income disparities.[22] The formula for the income inequality index (τ) is as follows:

$$\tau = \frac{1}{N}\sum_{i=1}^{N}\frac{x_i}{\mu}\ln\left(\frac{x_i}{\mu}\right)$$

Where x_i is the income of household i, N is the total number of households in the economy (685), and μ is the mean income of all households.[23] If the sample was perfectly egalitarian, all households in the dataset would have income equal to μ and the Theil index would be equal to zero. The larger the index, the greater the income inequality in the sample.

4. Results and discussion

4.1. Direct impacts for recipient households

We first examine the direct production effects of giving or converting land in our simulations, presented in Table 5. Each simulation was repeated 200 times, with each repetition involving a slightly different random draw of model parameter (Monte-Carlo procedure). The table reports the mean of those 200 values, as well as the standard deviation (SD, in italics), giving confidence brackets around each value. Thus, within the range of values obtained all our repetitions of simulation 1, the small fish-farmer increased fish production by $682 on average, with $144 standard deviation. Reporting results in such fashion helps us convey the robustness of our results to the variation and uncertainty in the data used for calibration.

The table shows that giving a small fish-farming household an additional acre of pond lets it increase revenue by $682 (SD = $144), while in simulation 2, handing a similar acre of pond to a large fish-farmer generates $557 (SD = $122) in revenue for that farmer. This is slightly less than in simulation 1, reflecting the fact that small households farm their ponds somewhat more intensively. However, the difference in overall productivity between small and large fish farmers is slight.

Simulation 3 allows the crop farmer household to gain $148 (SD = $24) in crop value, much less than giving a pond to either fish farmer. This suggests that aquaculture generates over four times more value per acre than agriculture, consistent with field observations.

In simulations 4 and 5, we account for the opportunity cost of crop land: the fish farmer converting an acre of land from cropland to pond needs to forego some crop production in order to increase fish production (about $165). Nevertheless, the revenue generated on that plot remains higher even when accounting for this opportunity cost, with small fish-farmers increasing revenue by $517 (SD = $153) and large fish farmers by $393 (SD = $132).[24]

4.2. Labor market and production input demands

Farming the new plot or pond requires inputs. Increased input demand is one of the primary conduits of the spillover impacts we aim to evaluate with this model. Table 6 presents the changes in

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[20] We do not model giving a pond to the crop farmer household because we do not have fish-farming production parameters for them (crop-farming household do not participate in any fish farming activity, by definition). We could assume that these farmers would act the same way a small fish farmers act, which would be largely redundant to simulation 4.

[21] Excavating a pond costs the same price no matter which household does it, so it can be assumed away in the comparison.

[22] Since the model groups all households into five types, it does not lend itself to the drawing of income distributions or Lorenz curves. For this reason, we opted to measure inequality with the Thiel index rather than the Gini coefficient.

[23] Since the model groups households into categories, we divided totals by the number of households represented in each group to recover household-level variables.

[24] These simulations focus on pond operation alone, excluding pond construction, which would potentially increase labor needs and associated spillovers in the first year, but not in any of the following years. Including it would likely further increase simulated spillovers from aquaculture, although these tasks are increasingly being performed by mechanical backhoes hired from outside of the cluster, which do not generate local spillovers. Excluding the pond construction channel makes our spillover results more conservative.

Table 5
Direct impacts on production for household receiving the plot.

	sim1	sim2	sim3	sim4	sim5
Change in fish production value by recipient household ($)	682	557	0	682	557
(SD)	*(144)*	*(122)*	–	*(144)*	*(122)*
Change in crop production value by recipient household ($)	0	0	148	−165	−164
(SD)	–	–	*(24)*	*(53)*	*(49)*
Revenue from new/converted plot for recipient household ($)	**682**	**557**	**148**	**517**	**393**
(SD)	*(144)*	*(122)*	*(24)*	*(153)*	*(132)*

Table 6
Factor demands associated with the received or converted acre of land/pond.

	Sim 1	Sim 2	Sim 3	Sim 4		Sim 5	
Household receiving the acre	Small fish farmer	Large fish farmer	Crop farmer	Small fish farmer		Large fish farmer	
Production activity	Fish	Fish	Crop	Fish	Crop	Fish	Crop
Increased demand for:							
Labor	**85**	**36**	**13**	**85**	**−16**	**36**	**−15**
(SD)	*(46)*	*(26)*	*(7)*	*(46)*	*(11)*	*(26)*	*(8)*
Purchased inputs	**250**	**259**	**60**	**250**	**−67**	**259**	**−68**
(SD)	*(74)*	*(92)*	*(18)*	*(74)*	*(28)*	*(92)*	*(29)*
Seed (fish or grain)	**78**	**50**	**15**	**78**	**−17**	**50**	**−17**
(SD)	*(16)*	*(11)*	*(3)*	*(16)*	*(5)*	*(11)*	*(5)*
Other expenses	**102**	**46**	**2**	**102**	**−2**	**46**	**−2**
(SD)	*(22)*	*(10)*	*(0)*	*(22)*	*(1)*	*(10)*	*(1)*

labor and input requirements of the fish or crop activity performed on the new plot. Note that the table focuses only on the household receiving the acre and the specific activity performed on that acre, not yet on the indirectly affected activities and households.

In simulation 1, the small fish farmer needs an additional $85 (SD = $46) worth of labor to farm the new pond it received. It also requires $250 (SD = $74) worth of feed, $78 (SD = $16) worth of fish seed, and $102 (SD = $22) in other expenses and operating costs.

The large farmer receives a pond in simulation 2, the farming of which requires an additional $36 worth of labor inputs, $259 of feed, $92 of fish seed and $56 in other expenses. As noted in the calibration section, the large farmer relies less on labor for production, therefore the increased labor requirements are much smaller for the large fish-farmer in simulation 2 than for the small fish-farmer in simulation 1.

The crop farmer receiving an acre of plot in simulation 3 also requires inputs to farm it: $13 of labor, $60 of crop inputs, $15 of seed and $2 in other expenses. Those input requirements are proportionately smaller compared to those required when operating an acre of pond, whether as a small or a large fish farm.

Simulations 4 models an acre of land that was converted from crop farming to fish farming, and thus features two columns: as the farmer increases input demand to engage in fish-farming, she also simultaneously decreases demand for crop farming inputs. Since the farmer increases production by the same amount as in simulation 1, the fish column of simulation 4 is identical: the farmer needs $85 of labor, $250 of feed, $78 of seed and $102 of other expenses to farm fish on the acre. At the same time, the farmer ceased crop production on the acre, with an associated reduction in input demand of $16 for labor, $67 for inputs, $17 for seed and $2 for other expenses. The net impact of the conversion on demand for inputs is clearly positive, which is partly why fish farming will tend to generate more spillovers in the rural economy than crop farming. The same analysis holds for simulation 5.

4.3. Labor market spillovers

Income spillovers materialize in part when non-recipient households supply the inputs required by the new activity. Switching to the supply side, we focus on the labor market, which is one of the dominant spillover channels, but the reasoning is analogous to that for other input and factor markets.

Fig. 2 shows which households provide the increased labor to the market in each simulation. In all simulations, non-farm households provide the bulk of the labor force. Crop farmers also participate in labor markets, and provide most of the remainder of the labor force in all simulations. Fish farming households (small farms, large farms, and nurseries), who represent about 10% of the population, make only small contributions to the labor force.

Simulations 1 to 3 all require an increase in labor supply in the economy to satisfy the demand needed to operate the additional acre. In simulations 4 and 5, the conversion releases crop-farming labor while increasing demand for fish-farming labor, but since fish farming is more labor intensive than crop farming, simulations 4 and 5 also lead to a net increase in labor supply.

Overall, small fish farms create much higher labor demand than large fish farms or crop farms, on a per-acre basis. Fig. 2 shows that simulations 1 and 4 entail a much larger increase in labor supply than the others. One reason is that, as shown in Table 6, smaller fish farmers apply more labor per acre in their production process, while large farms benefit from economies of scale and capital-intensive technology. Handing small fish farmers an acre of land thus leads to a greater labor demand. Another reason is that smaller farms also use more local inputs and generate slightly

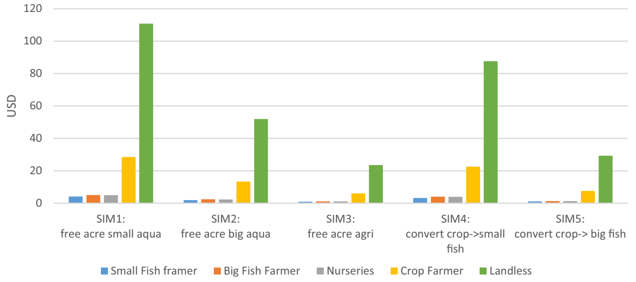

Fig. 2. Change in labor supply, by type of household (value in USD). Source: simulation results.

Table 7
Production impacts in simulation 1, all households.

	Small fish farmer	Large fish farmer	Fish Nursery	Crop farmer	Landless
Crop	0	0	0	0	0
Fish	**682**	−**97**			
	(144)	*(52)*			
Fish Seed	**2**	**49**	**101**		
	(1)	*(26)*	*(36)*		
Other local production			−**1**	−**2**	−**8**
			(0)	*(1)*	*(6)*
Retail	**4**	**7**	**28**	**28**	**79**
	(3)	*(5)*	*(18)*	*(15)*	*(27)*
Services	**0**	**9**	**1**	**3**	**24**
	(0)	*(5)*	*(1)*	*(2)*	*(8)*

higher incomes from an acre, which also amplifies the labor demand as a second-order effect.

Indeed, not all the additional supply of labor is responding directly to demand on the new/converted acre. Some of it also goes to satisfy labor demand in the activities stimulated by secondary impacts: seed-producing nurseries, input providers, shops where farmers spend their now-higher incomes, etc. The LEWIE model allows us to include these secondary impacts in our evaluation.

4.4. Impacts on all production in the cluster

As the recipient household makes use of the new or converted plot of land, they create cascades of effects that alter economic incentives in the economy. All households face new supply and demand conditions for the inputs they use and for the goods and services they sell, which leads them to change their production decisions. We outline those details in Table 7, focusing on simulation 1.

The direct impact of simulation 1 is to increase fish production by the small fish-farming household by $682 (SD = $144). This requires fish seed, which will be provided by local households as a secondary production impact. Fish seed is mostly produced by the nursery household ($101), but also the large ($49) and small ($2) fish farmer households. Meanwhile, the large fish farmer is facing increased competition and input costs, thus it shifts resources away from fish farming and reduces its production of fish by $97 (SD = $52).

As households are purchasing more inputs and enjoying higher incomes, spending increases on goods and services in the economy. All households participate to those activities to a certain extent, but the largest providers are the landless households, increasing their retail output by $79 (SD = $27) and services output by $24 (SD = $8). This is done, to a certain extent, at the expense of other local production, which in marginally decreases because households shift resources away to the more profitable activities.

It is noteworthy that the small fish farmer group, the recipient household in simulation 1, also captures some of the spillovers, through small increases in their fish seed, retail, and services outputs. In this case, these effects are very limited in comparison with the direct effect.

Similar secondary production effects are at play in all simulations. In the interest of conciseness, we aggregate them at the cluster level in Fig. 3. It shows total production impacts in the community, including both the household receiving the land and all other households. Each bar represents the total change in value of locally produced output for a given commodity in a given simulation. As such, the first bar shows that handing a small fish-farming household an additional acre of land generates a value of $585 (SD = $126) in fish production in the economy, as the small farmer who received the pond increases output by $682, and the large farmer scales back production by $97 in response to the new market conditions.

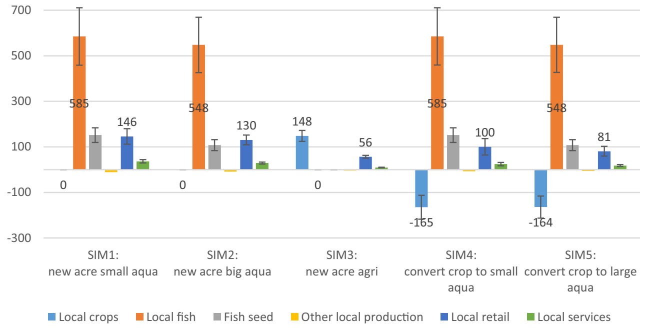

Fig. 3. Change in total value of local production (USD). Source: simulation results.

Total fish production increases by $548 (SD = $121) in simulation 2, when the large fish farmer is receiving the additional acre, slightly less than in simulation 1. In addition to shifts in fish and crop production, simulations 1 and 2 raise the total production of fish seed, by $152 and $108 respectively. All simulations also lead to an overall increase in retail output, which provides farm inputs and consumer goods. The retail spillover is far from negligible, ranging from $56 (SD = 7) in simulation 3 to $146 (SD = 37) in simulation 1. By comparison, the crop production impact in simulation 3 is $148.

Finally, the simulations reveal modest impacts on other activities. All simulations increase slightly the supply of service activities (the maximum was $37 in simulation 1), in response to rising incomes. All simulations also lead to very small decreases in the value of other local production such as artisan crafts, but in almost negligible amounts (the largest decrease was of $11 in simulation 1). These slight decreases are due to the reallocation of productive resources away from those activities and in favor of aquaculture, and are small because these resources are in fairly elastic supply, notably labor. Running our simulations with inelastic labor supply forces households to reduce other local production more, but does not substantially alter other results presented.

4.5. Net impacts on income

In this subsection, we report the total change in income for each household type in the model, summing up the direct income from the farming activities with all the spillover incomes a household may obtain through backward and forward linkages. In Fig. 4, each group of bars represents the five types of households in the

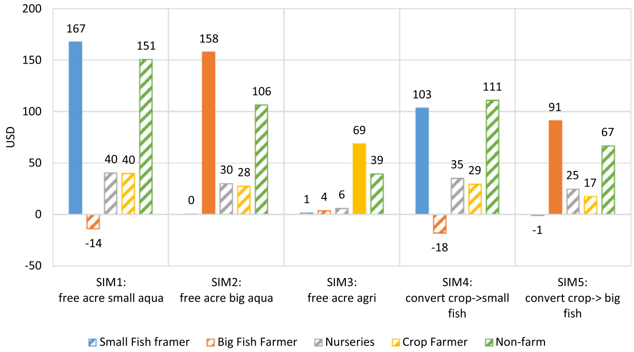

Fig. 4. Change in household income, by type of household. Source: simulation results. Full-colored bar represents the household receiving the land in each simulation. Confidence brackets not reported in the interest of clarity.

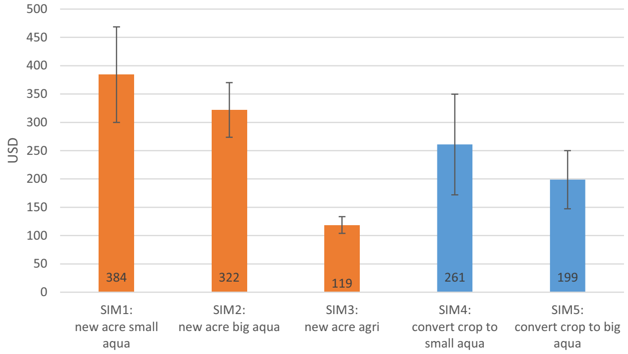

Fig. 5. Change in total real income in the economy. Source: simulation results.

economy for each given simulation. In each group, the full-color bar represents the recipient household, while other households are represented by striped bars. The figure reports the net effects on household income in real terms, summing across all income sources, netting out production costs, and accounting for changes in consumption prices (a local CPI is computed in the simulations).

In simulation 1, the tallest bar ($167) represents the net increase in household income for the small fish farmer (the recipient of the pond). This amount reflects the profits from increased fish production, as well as profits from other activities or income from the sale of labor to other households. Nursery farms also gain a modest income ($40) providing the seed for the new pond, mirroring the increase in fish seed production seen in Fig. 3. Large fish farmers are the only household type to lose income in simulation 1 (-$14). This is because the additional demand for fish seed and labor bids up the prices of these items (which are in limited, albeit elastic supply). This raises costs for all fish farmers, including large farms. This observation serves as an important reminder that, as with any intervention, market dynamics are likely to create losers alongside the winners.

A striking result in simulation 1 is that the bar representing non-farm households ($151) is nearly as tall as the bar for small fish farmers. Non-farm households are landless households who provide a large share of the labor working on fish farms. Non-farm households also participate in commerce (at all scales): they benefit from the extra spending needed for production on the additional pond, and from the multiple rounds of consumption spending triggered by increased incomes in the economy. Retailers benefit from purchases made by the small fish farmers, by the laborers who worked the new pond, the nursery farm who provided the seed, the retailers who sold goods to them, etc. This highlights the importance of forward and backward linkages, particularly in input, labor and retail markets. Non-farm households are among the two top gainers in all simulations, and in simulation 4, they even gain more than the household receiving the land. Crop farmers gain modest amounts of income through the same channels, as they also participate in the labor and retail markets.

Simulation 2 presents a very similar pattern to simulation 1, but with all bars somewhat smaller. The top gainers are the large farmers, who own the additional pond and see revenues increase by an amount just slightly lower than the revenue of small fish farms in simulation 1. The next largest gainers are non-farm households, but their income increases less than they did in simulation 1 by about a third ($106 against $151). Nurseries and crop farmers also gain less, while small fish farmers remain unaffected. An acre of pond operated by a large farm generates similar direct incomes as one operated by a small farm, but substantially lower indirect incomes.

Results from simulation 3 show that only two household types gain significantly from the transfer of an acre of cropland: the crop farming household itself ($69), and the non-farm household ($39). Fish farmers and nurseries gain only fractional amounts, which are the net balance of the gains and losses they may experience by their participation in labor and input markets. This confirms that that crop farming produces far fewer spillovers than fish farming, because it generates less demand for hired labor and does not rely on a local nursing industry.

Aggregating all these income effects, in Fig. 5 we report the overall impact of each of the five simulations on total income in the economy. Each bar should be interpreted as the change in annual income triggered by the simulated shock, summed across all households.

Comparing simulations 1 and 2 to simulation 3, we see that overall, an acre of pond generates far more income in the economy than an acre of crop land ($322–$384 against $119). This is expected, because an acre of pond is also worth more than crop land. The model simulates each scenario by increasing landholdings by the value of one acre: since the rental rate for ponds (USD 166) is higher than the rental rate for cropland (USD 58), simulations 1 and 2 are effectively simulating “gifts” of more valuable land.

The bars in simulations 4 and 5 are smaller than in 1 and 2, because farmers are using their existing land on which they were previously farming crops, thus they incur an opportunity cost themselves from decreased crop farming, and impose an opportunity cost on the economy with the associated loss of business for input providers. However, the positive bars in simulations 4 and 5 confirm that, from an economywide perspective, aquaculture generates higher revenues per acre than crops.[25]

Comparing simulation 1 to simulation 2, we also see that giving an additional acre of pond area to a small fish farmer generates about 20% more income in the economy ($384, SD = $84) than handing the same pond to a large fish farmer ($322, SD = $48). The same is true with simulations 4 and 5: the total income generated by the conversion in the former ($261, SD = $89) is about 30% higher than in the latter ($199, SD = $51).

4.6. Total spillovers

One measure of total spillover impacts can be summed up by contrasting, for each simulation, the income of the household receiving land in each simulation to the summed income of all

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[25] This is true even though the simulations compare only farm operation, not including pond construction expenditures.

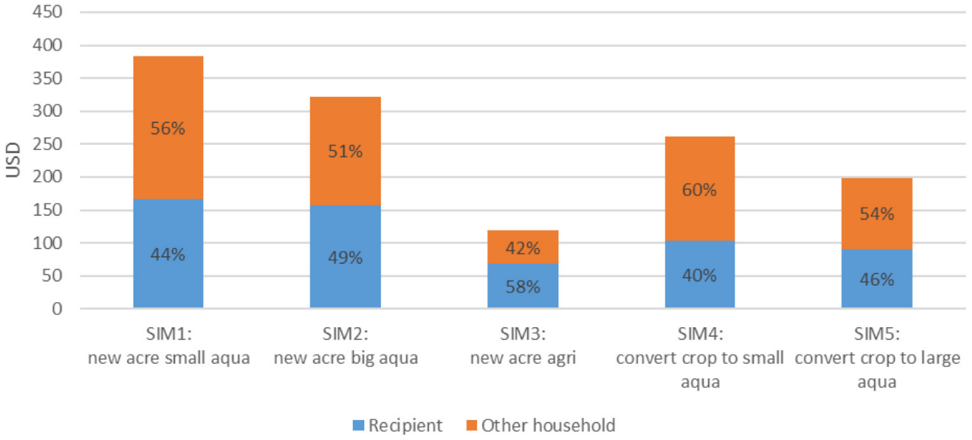

Fig. 6. Increases in real income for recipient and non-recipient households. Source: simulation results.

other households.[26] Fig. 6 shows the same bars as Fig. 5, but split between recipients of the acre, and all other households.

All interventions create a non-negligible spillover, between 42% and 60% of the total income generated. In 4 out of our 5 simulations, the share of income accruing to non-recipients is above 50%, meaning that the indirect benefits generated through market spillovers are larger than the direct benefits accruing to the household who received the land. This highlights the economic interconnectedness of rural households and the importance of accounting for income spillovers when discussing rural economies.

Simulation 3 shows that 42% of the additional income generated by an extra acre of land accrues to households other than crop farmers. In simulations 1 and 2, the shares are 56% and 51%, respectively, indicating that fish farming generates greater spillovers than crop farming. This reflects the fact that aquaculture is more demanding of inputs and labor than crop farming, so that operating an additional acre of pond is more likely to generate spillover incomes. In addition, purchases of fish seed, which is always locally produced, generate local spillovers through backward linkages to commercial nurseries.

The figure also shows that small fish-farms generate more spillovers than large ones, both in absolute and relative terms. Small farmers given an acre of pond retain 42% of the total income generated, while large farmers retain 49%. When they convert a crop field to a pond, small farmers retain 40% of benefits, while large farmers retain 46%. This reflects the difference in production technologies: large farms use more capital-intensive technology, thus channeling more benefits to capital owners.

4.7. Impacts on inequality

Lastly we turn to the impacts of aquaculture on inequality in the local economy. Fig. 7 shows the percent change in the Theil index for income associated with each simulation. An increase in the index represents an increase in inequality, and vice-versa.[27] Numbers are small because the value of the income created by a single pond represents a small fraction of the value of the total income in the modelled economy.

Simulations 1 and 4 slightly reduce income inequality (−0.01% and −0.02% respectively), while simulations 2 and 5 increase it (0.09% and 0.05%). Meanwhile, an additional acre of crops has a negligible impact on inequality (sim 3). These results can be interpreted as follows. Large fish farm households are among the wealthiest in the aquaculture cluster. Increasing their incomes, either by increasing their landholdings (sim 2) or converting agricultural land to ponds (sim 5) amplifies this inequality. A small fish farmer receiving or converting land to ponds has an inequality reducing effect, because although they are somewhat better off than the population average, they generate large indirect income spillovers to landless laborers who sit at the lower end of the income distribution. For crop farmers, the small inequality increasing (direct) and inequality reducing (indirect) effects of raising landholdings cancel one another out.

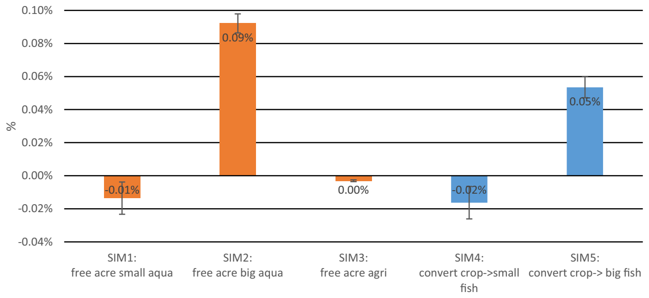

Fig. 7. Percent change in the Theil index of income inequality. Source: simulation results.

5. Conclusions

This article presents the first structural model analysis of the relationship between fish farms and the local economy to which they belong. We constructed a LEWIE model of the economy of 25 fish farming village tracts in Myanmar, and used the model to: (1) simulate the economy-wide impacts of utilizing land for either aquaculture or crop production; (2) compare spillovers generated by small- and large-holder operated fish farms.

This analysis yielded the following results: First, as expected, fish farming in Myanmar generates much higher returns per acre to the farmer than agriculture. Second, importantly for the debate on aquaculture's contributions to economic development, fish farming creates income spillovers for surrounding households, the largest of which accrue to landless farm workers. Third, small commercial fish farms generate slightly larger direct incomes per acre of pond than large farms, and substantially larger spillover

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[26] Strictly speaking, the recipient household also perceives "spillovers" through its participation in other activities (e.g. retail). However, these amounts are small, and since the household is reallocating its resources towards production on the new plot, on balance its income from those sources tends to decrease.

[27] The magnitudes (-0.04%, 0.06% etc.) measure the percent increase in the entropic distance from the egalitarian state in the simulation.

incomes. This is due to the propensity of the former to rely more heavily on labor and locally produced inputs, while the latter use more external inputs and capital. Fourth, increasing the area of ponds operated by fish farming smallholders has an income inequality-reducing effect, while the expansion of large fish farms raises inequality.

Our work makes three significant contributions. First, the methodological toolkit developed allows aquaculture to be viewed through an economy-wide lens that situates fish farms within the networks of forward and backward linkages that ultimately determine their performance as drivers of rural growth. Formalizing these linkages in a structural model rooted in general equilibrium theory allows the debate over the economic impacts of aquaculture to be addressed within a theoretical framework capable of generating robust empirical results.

Second, the findings contribute to ongoing debates over the role of aquaculture in poverty alleviation. Our results show that commercially-oriented fish farms can have positive impacts on the local economy through income spillovers, and lend strong empirical support to the "SME narrative" on aquaculture's role in rural development.

Third, simulation results have important policy implications, for Myanmar and beyond. The finding that aquaculture can generate much higher farm incomes *and* greater economic spillovers than crop farming is pertinent for Myanmar, where conversion of agricultural land to ponds is prohibited, and to many other countries that place restrictions on the expansion of aquaculture in the attempt to protect of cropland (such as Vietnam, China, and India among others). The finding that large fish farms generate smaller spillovers than small commercial fish farms *and* increase local income inequality is of special significance for Myanmar, where agricultural and land use policy have historically favored industrial-scale fish farm development, indicating that a reorientation of policy support toward smallholder-led aquaculture development is in order.

Acknowledgements

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Appendix I

LEWIE model statement

Table A1
Set, subset and mapping names used in model statement.

Sets			
g	commodities	f	factors
h or hh	households		
h or hh	households		
Subsets			
gtv	Goods locally tradable	fk	Fixed factors
gtz	Goods traded in outside markets	ft	Locally tradable factors
gp	Locally produced goods	ftw	Factors traded in outside markets
gag	Agricultural goods	fpurch	Purchased variable inputs
gnag	Nonagricultural goods		
Mappings			
maphv(h,v)	Mapping of households to cluster		

Table A2
Commodities, factors, households.

Commodities	
Crop	Crops produced or consumed within the cluster
Meat	Meat produced or consumed within the cluster
Fish	Fish produced or consumed within the cluster
Fish seed	Fish eggs, hatchlings or fingerlings produced locally
Retail	Local retailers in the cluster
Services	Local Services provided within the cluster
Production	All other local production, such as crafts or food processing
Outside good	Any commodity purchased outside the local economy
Factors	
Labor	Labor (family and hired receiving wage in cash or kind)
Land	Crop land or ponds

Table A2 (*continued*)

Capital	Capital
Input	Purchased production inputs (feeds and fertilizers)
Households	
Small fish farm	Fish farms with total pond area < 10 acres
Large fish farms	Fish farms with total pond area > 10 acres
Nurseries	Fish farms specialized in nursery activity (no growout)
Crop farms	Crop farms
Non-farm	All households with no farming activity (fish or crop), including landless farm workers.

Table A3
Variable names used in model statement.

Variables			
Values		Consumption and income	
PV(g,v)	price of a good at the cluster level	QC(g,h)	quantity of g consumed by h
PZ(g)	price of a good at the regional level	Y(h)	nominal household income
PH(g,h)	price as seen by household h (=PV or PZ)	RY(h)	real household income
PVA(g,h)	price of value added net of intermediate inputs	CPI(h)	consumer price index
R(g,f,h)	rent for fixed factors	TROUT(h)	transfers given by a household of others
WV(f,v)	wage at the cluster level	SAV(h)	household savings
WZ(f)	wage at the regional level	EXPROC(h)	household expenditures out of the region
Production		Trade	
QP(g,h)	quantity produced of a good by a household	HMS(g,h)	household marketed surplus of good g
FD(g,f,h)	factor demand of f in production of g	VMS(g,v)	cluster marketed surplus of good g
ID(g,gg,h)	intermediate demand for production of g	ZMS(g)	Regional marketed surplus of a good
QVA(g,h)	quantity of value added created	HFMS(f,h)	factor marketed surplus from the household
HFD(f,h)	factor demand in the household	VFMS(f,v)	factor marketed surplus out of the cluster
HFSUP(f,h)	labor supply from the household (elastic endowment)	ZFMS(f)	factor marketed surplus out of the region

Table A4
Parameter names used in model statement (GAMS).

Parameters			
Production		Consumption	
a(g,h)	Shift parameter in CD production function	alpha(g,h)	consumption share parameters in the LES
beta(g,f,h)	Factor share parameters (CD exponents)	cmin(g,h)	minimal consumption in the LES
vash(g,h)	Value-added share of output	exinc(h)	exogenous income of household
idsh(gg,g,h)	Intermediate input share	vmsfix(g,v)	fixed marketed surplus at the village level
fixfac(g,f,h)	Fixed factor endowments	Transfers	
vfmsfix(f,v)	Factors fixed at the local level (family, hired labor)	troutsh(h)	share of transfers in household expenditures
		exprocsh(h)	share of expenditures outside of cluster
endow(f,h)	Household factor endowments	savsh(h)	share of income saved
hfsupzero(f,h)	Initial labor supply	trinsh(h)	share of total transfers received by a given household
hfsupel(f,h)	Factor supply elasticity	For Experiments	
		fsim(g,f,h, sim)	Exogenous change in factor endowment in the simulation (land)
pibudget(g,h)	Liquidity constraint on inputs		
pibsh(g,h)	Share of pibudget to good g		

Table A5
Equation definitions.

Equation name	Description
**Prices*	
EQ_PVA(g,h)	prive value added equation
EQ_PH(g,h)	market price as seen from household h
**Production*	
EQ_FDCOBB(g,f,h)	factor demands cobb douglas
EQ_QVACOBB(g,h)	quantity VA produced cobb douglas
EQ_QP(g,h)	quantity produced from QVA and ID
EQ_ID(gg,g,h)	quantity of ID needed for QP
**Consumption*	
EQ_QC(g,h)	quantity consumed
**Income*	
EQ_Y(h)	full income constraint for the household
EQ_CPI(h)	consumer price index equation
EQ_RY(h)	real household income equation
**Transfers*	
EQ_TRIN(h)	inter household transfers in (received)
EQ_TROUT(h)	interhousehold transfers out (given)
**Exogenous expenditures*	
EQ_SAV(h)	savings (exogenous rate)
EQ_EXPROC(h)	expenditures outside of the zoi (exogenous rate)
**Goods market clearing*	
EQ_HMKT(g,h)	qty clearing in each household
EQ_VMKT(g,v)	market clearing in the village
EQ_ZMKT(g)	market clearing in the zoi
EQ_VMKTfix(g,v)	price definition in the cluster
EQ_ZMKTfix(g)	price definition in the zoi
**Factor market clearing*	
EQ_HFD(f,h)	total household demand for a given factor
EQ_FCSTR(g,f,h)	fixed factors constraint
EQ_HFSUP(f,h)	household elastic supply
EQ_HFMKT(f,h)	tradable factor clearing in the household
EQ_VFMKT(f,v)	tradable factors clearing in the village
EQ_ZFMKT(f)	tradable factor clearing in the zoi
EQ_VFMKTfix(f,v)	wage determination for tradable factors clearing in the village
EQ_ZFMKTfix(f)	wage determination for tradable factors clearing in the zoi

Table A6
Equations in the model.

Name	Equation
1) Household equations	
Price Block	
EQ_PH(g,h)..	$PH_{g,h} = \left[PZ_g\right]_{g \in gtz \cup gtw} + \left[\sum_{v \mid maphv(h,v)} PV_{g,v}\right]_{g \in gtv}$
EQ_PVA(g,h)..	$PVA_{g,h} = PH_{g,h} - \sum_{ga} idsh_{ga,g,h} \times PH_{ga,h}$
Production Block	
EQ_QVACOBB(g,h)..	$QVA_{g,h} = a_{g,h} \times \prod_f \left(FD_{g,f,h}\right)^{\beta_{g,f,h}}$
EQ_FDCOBB(g,f,h)	$\left[R_{g,f,h}\right]_{f \in fk} + \left[WZ_f\right]_{f \in ftz} + \left[\sum_{v \mid maphv(h,v)} WV_{f,v}\right]_{f \in ftv} = \frac{PVA_{g,h} \times QP_{g,h} \times \beta_{g,f,h}}{FD_{g,f,h}}$
EQ_QP(g,h)	$QP_{g,h} = QVA_{g,h} / vash_{g,h}$
EQ_ID(gg,g,h)..	$ID_{ga,g,h} = QP_{g,h} \times idsh_{ga,g,h}$
Consumption and income block	
EQ_QC(g,h)..	$QC_{g,h} = \frac{\alpha_{g,h}}{PH_{g,h}} \times \left(Y_h - TROUT_h - SAV_h - EXPROC_h - \sum_{ga} PH_{ga,h} \times cmin_{ga,h}\right) + cmin_{g,h}$

Table A6 (*continued*)

Name	Equation
EQ_Y(h)..	$Y_h = \sum_{g,fk}(R_{g,fk,h} \times FD_{g,fk,h}) + \sum_{g,ftz} WZ_{ftz} \times HFSUP_{ftz,h} + \sum_{ftv}\sum_{v \mid maphv(h,v)} WV_{ftv,v} \times HFSUP_{ftv,h} + \sum_{ftw} WZ_{ftw} \times HFSUP_{ftw,h} + exinc_h$
EQ_TROUT(h)..	$TROUT_h = troutsh_h \times Y_h$
EQ_EXPROC(h)..	$EXPROC_h = exprocsh_h \times Y_h$
EQ_SAV(h)..	$SAV_h = savsh_h \times Y_h$
EQ_CPI(h)..	$CPI_h = \sum_g PH_{g,h} \times \alpha_{g,h}$
EQ_RY(h)..	$RY_h = \frac{Y_h}{CPI_h}$
2) Market closure	
Market clearing block for commodities	
EQ_HMKT(g,h)..	$HMS_{g,h} = QP_{g,h} - QC_{g,h} - \sum_{ga} ID_{g,ga,h}$
EQ_VMKT(g,v)..	$VMS_{g,v} = \sum_{h \mid maphv(h,v)} HMS_{g,h}$
EQ_ZMKT(g)..	$ZMS_{g,v} = \sum_v VMS_{g,v}$
EQ_VMKTfix(gtv,v)..	$VMS_{gtv,v} = vmsfix_{gtv,v}$
EQ_ZMKTfix(gtz)..	$ZMS_{gtz} = zmsfix_{gtz}$
Market clearing block for factors	
EQ_HFV(f,h)..	$HFD_{f,h} = \sum_g FD_{g,f,h}$
EQ_FCSTR(g,fk,h)..	$FD_{g,fk,h} = fixfac_{g,fk,h}$
EQ_HFMKT(ft,h)..	$HFMS_{ft,h} = HFSUP_{ft,h} - \sum_g FD_{g,ft,h}$
EQ_HFSUP(ft,h)..	$\frac{HFSUP_{ft,h}}{hfsup^0_{ft,h} + hfsnewref_{ft,h}} = \left[\sum_{d \mid maphd(h,d)} (WD_{ft,d})^{\zeta_{ft,h}}\right]_{f \in ftd} + \left[(WZ_{ft,d})^{\zeta_{ft,h}}\right]_{f \in ftz \cup ftw}$
EQ_VFMKT(ft,v)..	$DFMS_{g,d} = \sum_{h \mid maphd(h,d)} HFMS_{g,h}$
EQ_ZFMKT(ft)..	$ZFMS_{ft} = \sum_v VFMS_{ft,v}$
EQ_VFMKTFIX(ftv,v)..	$VFMS_{ftd,d} = vfmsfix_{ftv,v}$
EQ_ZFMKTFIX(ftz)..	$ZFMS_{ftz} = zfmsfix_{ftz}$
For simulations with a budget constraint	
EQ_FDCOBB(g,f,h) (only for purchased factors)	$FD_{g,f,h} \times WZ_f = pibudget_{g,h}$

Appendix II

Parameter estimations

Table A7
Log-log regression results for fish, fish seed, and crop production functions.

Factor demands estimations:	Small fish farm	Large fish farm	Nursery farms or fish farms	Crop farm or other farm households
Dependent variable:	Fish output value	Fish output value	Fish seed value	Crop value
Independent variables:				
Labor	0.17	0.03	0.17	**0.10****
(SE)	*0.09*	*0.10*	*−0.12*	*−0.04*
Land	**0.35*****	**0.27****	**0.49*****	**0.199****
(SE)	*0.09*	*0.10*	*−0.18*	*−0.10*
Capital	−0.04	0.07	0.03	**0.26*****
(SE)	*0.04*	*0.04*	*−0.16*	*−0.07*
Purchased inputs	**0.53*****	**0.61*****	**0.29*****	**0.45*****
(SE)	*0.07*	*0.06*	*−0.22*	*0.09*
Constant	**1.81*****	**1.72*****	**2.08*****	**4.02*****

(*continued on next page*)

Table A7 *(continued)*

Factor demands estimations:	Small fish farm	Large fish farm	Nursery farms or fish farms	Crop farm or other farm households
(SE)	*0.20*	*0.17*	*−0.40*	*−0.90*
N	46	79	55	70
F-stat	41.8	154.5	17.6	185.6

Note: Stars indicate significance levels (*:10%, **:5%, ***:1%).

Table A8
Log-log regression of output on labor for other production, services, and retail production functions.

Factor demands estimations:	All households	All households	All households
Dependent variable:	Other production value	Services value	Retail value
Independent variables:			
Labor	0.293	0.411	0.415
(SE)	*(0.277)*	*(0.27)*	*(0.209)*
Constant	**3.757*****	**3.529***	**3.535*****
(SE)	*(0.499)*	*(0.728)*	*(0.359)*
N	9	5	17
F-stat	1.11	2.33	3.92

Note: Capital input shares assumed to be 1 minus the labor input share.

Table A9
Intermediate input shares, by activity.

	Small fish farm	Large fish farm	Nursery farm	Crop farm (and other farming households)	All households		
Activity:	Fish output value	Fish output value	Fish seed value	Crop value	Other production value	Services value	Retail value
Intermediate input shares:							
Local crops	0.00	0.00	0.00	0.10	0.00	0.00	0.00
Local meat	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Local fish	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Local fish seed	0.11	0.09	0.54	–	–	–	–
Other local production	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Local retail	0.00	0.00	0.00	0.00	0.24	0.22	0.30
Local services	0.00	0.00	0.00	0.01	0.00	0.00	0.00
All expenditures outside the cluster	0.15	0.08	0.28	0.10	0.15	0.14	0.38

Table A10
Value of items purchased or consumed by household type (MMK 100,000).

	Small fish farm	Large fish farm	Nursery farm	Crop farm	Non-Farm
Local crops	8.3	8.4	5.7	8.0	6.5
Local meat	5.4	7.7	4.7	4.3	3.7
Local fish	2.7	4.3	2.2	2.1	2.0
Other local production	1.3	8.0	1.6	0.9	2.5
Local retail	11.2	40.3	14.6	17.0	9.9
Local services	7.0	17.4	7.3	4.0	2.9
All expenditures outside the cluster	15.5	64.2	15.7	7.1	7.2
Total	**51.4**	**150.3**	**51.8**	**43.4**	**34.6**

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