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COMPETING WITH THE MIDDLEMEN TO
INCREASE MARKET ACCESS IN THE AMAZON

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ABSTRACT

Middlemen are ubiquitous in supply chains. In developing countries they help bring products from remote communities to end markets but may exert strong market power. We study a cooperative intervention which organizes together poor fishing communities in the Amazon — one of the poorest and most remote regions of the world — to purchase large boats in order to partially bypass middlemen and deliver their fish directly to market. We find that the intervention increases income by 27%, largely through an increase in price received, and also increases consumption. Moreover, the intervention is highly cost effective with the projected stream of income gains easily covering the cost of the investment. Finally, we formalize a model in which the market power of middlemen itself can create a poverty trap, which can be eliminated with cooperative investment.

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1 Introduction

The geographic concentration of both economic activity and poverty are well known facts of economic development. Remoteness itself, together with limited access to markets, can magnify poverty and even entrap those in rural areas in poverty. This motivates investment in transportation infrastructure, but large scale infrastructure investments are often prohibitively expensive, fraught with political economy issues, or infeasible for developing countries.¹ Are there alternative, cost-effective ways to spur economic development in rural areas where public infrastructure is limited?

We study exactly such an intervention in one of the most remote settings in the world, the impoverished fishing communities of the Brazilian Amazon. Here boats themselves, including floating stores that visit periodically, are the only access to outside markets. Fishing itself is straightforward; while labor-intensive it does not involve much uncertainty. Instead, the challenge is delivering the good to market. With a seasonally-harvested and highly-perishable good – a huge, pre-historic, air breathing fish called a pirarucu – these communities’ only direct access to the final market would involve multi-day ferry rides to Manaus, the capital city of Amazonas. Instead, they sell to middlemen, part of a cartelized supply chain, who arrive infrequently and with acute market power. The intervention we study is an NGO-initiated but community-financed procurement of boats (together with ice and fuel, the necessary complementary inputs), which enables communities to cut out the middlemen and bring the goods to market themselves. We posit that the intervention may yield direct effects, where communities sell directly to the end market rather than to intermediaries, indirect effects, where communities continue to sell to middlemen but with greater bargaining power, or both.

To evaluate the intervention, we conduct surveys in affected communities combined with other administrative data sources. For the purposes of evaluating the intervention, we benefit from plausibly exogenous variation in which communities received boats: although boats were ordered at the same time, shipwrights were unable to fulfill all orders properly for the 2018 fishing season. Remarkably, we find that the intervention increased income substantially, by 27% over income in the control communities. There is also evidence that it increased consumption, including food expenditures. We find no significant increase in

¹For the benefits of large scale infrastructure investments, see, for example, [Donaldson \(2018\)](#); [Lu \(2020\)](#); [Asturias et al. \(2019\)](#); [Asher and Novosad \(2020\)](#). For the challenges, see [Alder and Kondo \(2020\)](#); [Burgess et al. \(2015\)](#); [Jedwab and Storeygard \(2020\)](#).

fishing, however – important in a situation where overfishing could plausibly be a concern – but instead an increase in the price received for the fish themselves. Not only do we find direct evidence of welfare improvements, but our cost-benefit analysis shows the boat investment to be cost-effective as well. Extrapolating the additional revenues over time, the boats would potentially pay for themselves in under 3 years, well within the life of the typical boat.

Our impact regressions evaluate the effect of receiving a boat in the endline data, after controlling for baseline and time-invariant characteristics, such as distance to market. Identification of unbiased causal impact estimates rests on the conditional exogeneity of which communities received boats. In balance tests, we find only one statistically significant difference ($p < 0.05$) in our baseline surveys, at a rate that is not out of line with type II errors. This difference, however, is in baseline fishing levels, and so we control for these in our baseline estimation. Moreover, using historical administrative data we find no differential trends in fishing.

We study impacts on household-level income, consumption, travel, and time use. The impact on monthly income of R\$184 is significant at the 5% level. The impact on income is of similar magnitude to the overall impact on monthly consumption of R\$148, although the latter is not significant at conventional levels. Looking in more detail, we find roughly half of this increase is on food expenditures (significant at a 5% level) and an important component of the increase is on gas, although this is only marginally significant. We also find that households are more likely to travel to a distant city. Time use is unaffected.

To discover more about the increase in income, we evaluate the community level impacts based on data gathered from a community-level key informant survey. We find no significant impact on quantities sold, although our estimates are not precise. We do, however, find an increase in price of R\$0.77/kilogram, a 20 percent increase relative to the control (significant at a 5% level). This estimate is consistent with 60 percent of the community increase in pirarucu income coming mechanically from higher prices. Moreover, though not significant, our point estimate suggests that prices paid by middlemen may have increased as well. Indeed, our results are consistent with the intervention yielding an indirect effect in its first year: Communities do not appear to substitute away from selling to middlemen, but they may earn a higher price when selling to middlemen. We suspect that this may reflect a risk mitigation strategy in which communities continue to sell a substantial portion of their pirarucu to known buyers.

If the intervention is cost effective, why would the community members not have

implemented such a strategy on their own? We posit that, in the context of their economic environment, the lack of a boat constituted a poverty trap, especially in the presence of a cartel with market power in pricing. Theories of poverty traps often involve fixed costs. To fix ideas, we develop such a theory in which middlemen are capable of financing the large fixed cost of a boat, but poor communities are not. Given market power, they can pay below market prices (or equivalently charge a delivery price substantially above the true cost of transporting goods) that can create a man-made poverty trap, even when the natural cost structure does not lead to a poverty trap. We show how cooperative investment in the boats can allow people to escape this poverty trap both directly, the income of those who purchase the boat increases through lower transportation costs, and indirectly, by lowering the market power of middlemen, thereby improving the terms that remote producers receive.

The rest of this paper is organized as follows. After placing our contribution in the literature, Section 2 gives background to the fishing communities we study, their supply chain, and the intervention. Section 3 presents our empirical results, including balance tests, impact estimates, and cost-benefit analysis. Section 4 presents a simple theoretical explanation of our findings, while Section 5 concludes.

Related Literature

This paper is related to the literature that studies how access to outside markets affects people living in remote regions of developing countries. Often this is studied in the context of transportation infrastructure, such as roads or bridges. These papers often emphasize how market access affects labor markets ([Asher and Novosad, 2020](#); [Brooks and Donovan, 2020](#)), or reduces dispersion in prices across space ([Sotelo, 2020](#); [Van Leemput, 2016](#); [Aker, 2010](#)). Our emphasis on decreasing the market power of buyers in poorly connected markets is similar to the study of how roads affect competition in [Asturias et al. \(2019\)](#), who study how a major highway system affected market power in manufacturing firms. Our intervention is similar to roads in that it connects markets and involves high fixed costs, however it differs in a key way: roads allow local agents to access outside markets and for outside participants to more easily reach local markets, but community boats only increase market access for the local agents.

We join an important literature in development that studies the role of middlemen, and supply chains more broadly (e.g., [Burke et al., 2019](#); [Grant and Startz, 2021](#)). Here we follow an experimental approach like [Bergquist and Dinerstein \(2020\)](#), which finds that

Kenyan maize traders face very large start-up costs and capture a great deal of surplus. While their experiment focused on changing the behavior on the part of the middlemen, we focus on giving the communities an alternative to the middlemen.

Our paper also has similarities to [Jensen \(2007\)](#), which studies fisheries in the development context. In both that project and ours, price dispersion had welfare costs that could be mitigated with technology, though the nature of the friction in that case (information) is quite different than in ours (physical transportation). In each case we consider technologies that alleviate those frictions (mobile phones in that case and new boats in ours). We view the key difference between these interventions to be their cost. Once available and known, mobile phones can be widely adopted quickly with minimal need for outside intervention. However, due to the very high cost of boats relative to village income, it may be very difficult for communities to make the investment, even if everyone knows about the technology and knows that it has positive net present value. Like [Jensen and Miller \(2018\)](#), we study fishing boats, but they focus on the shipbuilding industry while we focus on the use of boats by fishermen.

On the theory side, our model extends the literature on poverty traps (e.g., [Banerjee and Newman, 1993](#); [Piketty, 1997](#); [Aghion and Bolton, 1997](#); [Ghatak and Jiang, 2002](#)) that assumed competitive markets. Using the case of intermediaries, we show how market power can create micro poverty traps, when a technological poverty trap would otherwise not exist.²

Finally, our paper joins a literature that studies questions related to the Amazon rainforest itself, though ours is unusual in that we focus on the economic behavior of people living deep in the jungle. Much of the existing literature focuses on the effects of human activity on deforestation, often in the context of farming (e.g., [Assunção et al., 2017](#); [Pfaff, 1999](#)). Presumably, the literature on economies deep in the jungle is limited by the difficulty of data collection.

²In that sense, it relates the earlier work of [Murphy et al. \(1989\)](#), but investments are not complementary in our model, so escaping the poverty trap does not require “big push” investment.

2 Background on the Brazil Amazon, Supply Chain, and Experiment

We study whether or not boats may offer a cost-effective means of increasing access to market for fishermen in 2 remote reserves, Mamirauá and Uacari, in the Brazilian Amazon. Partnering with Fundacao Amazonas Sustentavel (FAS), the leading environmental non-governmental organization in Brazil, we exploit plausibly exogenous variation in the timing in which communities gained access to boats.

2.1 Setting

The Amazon communities we study are remote and poor, and yet they have some advantages and remain where they are because of their longstanding lifestyle. Calling themselves “children of the forest,” the river communities living deep in the Amazon are among the most remote in the world. Although the State of Amazonas designated vast areas as protected reserves, such as the Mamirauá and Uacari Reserves, poor homesteading squatters are permitted to build their homes on any river front areas that they carve out of the forest. With a church, one room school, and meeting house, each community numbers from 4-40 families with an average of 17-18 households. Even though by income level these river communities are categorized as extremely poor, the plentiful fish and forest fruits combined with chickens and vegetables adds nutrition into their diet.

For river travel, these communities think not in terms of distance, but rather in terms of travel time or diesel cost to power their boats. As a frame of reference, the main commercial transport ferry travels upriver from the capital city of Manaus, Amazonas (population 2 million) to Fonte Boa (population 37,000) in Mamirauá in 2 days 21 hours. Traveling further upriver to Carauari (population 26,000) in Uacari takes the ferry an additional 3 days 13 hours, making the whole journey from Manaus 6 days 10 hours one way.

The annual pirarucu fishing season represents the main source of income for most river communities. Pirarucu (*arapaima giga*) is an ancient, air-breathing, giant fish native to the lakes in the Amazon River basin. One of the largest freshwater fish in the world, pirarucu regularly grow to 3 meters (10 feet) and 220 kilograms (480 pounds), although most are caught around 2 meters and 75-100 kilograms. The lakes themselves are formed when low water levels of the dry season separate them from the main river, entrapping the pirarucu. Once over-fished and endangered, careful fish management over the last decade has coaxed

pirarucu numbers up to such an extent that most communities catch pirarucu annually.

Though technically challenging, hunting pirarucu is a relatively straightforward process for the experienced fishermen, involving little of the yield uncertainty we often associate with fishing. The annual dry season and water level drop of the Amazon River by 15 meters (50 feet) signals the beginning of the pirarucu fishing season, usually at the end of August to November. Entire communities move inland to their designated lakes for a few weeks to engage in this collective effort. “Hunting” rather than “fishing” better describes the activity. Pirarucu must surface every 20-25 minutes to breathe air, and young men harpoon pirarucu as the fish come up to the surface to breathe while standing in their fragile, flat-bottom kayaks. Once the pirarucu are dragged to shore, all community members work together to clean and prepare the pirarucu and then carry them the 2-3 miles from their lake to the Amazon River.

2.2 Existing Supply Chain

While hunting is straightforward, the current pirarucu supply chain and market structure limits the value captured by fishermen through the sale of their fish. The boats of the regional middlemen, with ice-stocked holds of 20-30 ton capacities, arrive at the communities’ river docks to pick-up the catch. These middlemen have relationships with buyers in the regional market towns such as Fonte Boa and Carauri, or alternatively, transport the pirarucu to Manaus for sale to the eight fish processors (*frigorificos*). The ultimate consumer, the Amazonian public, considers pirarucu a delicacy and part of a traditional family meal to celebrate Holy Week between Palm Sunday and Easter every spring.

Figure 1 displays the prices received at each step of this pirarucu value chain in Mamirauá in terms of reais/kilogram (R\$/kg). Our primary focus in this paper is getting the product from fishermen to “regional buyers” or “local fish processors” (i.e., frigorificos) located in Manaus. First, note that without a large boat, fishermen have two options to sell fish: middlemen and local buyers (in either Tefe or Fonte Boa).³ Without a larger boat the latter option involves the risky and/or costly work of bringing the large, perishable fish into market towns using public ferries or the fishermen’s own smaller boats or kayaks. The price received is similar, but delivery to local buyers is costly. Delivery does not benefit from returns to scale, and ice and fuel are expensive in remote areas. Without ice there is

³A third option is to consume the fish themselves, but this is not common. Pirarucu are treated as a cash product, and the local diet consists more of eggs, vegetables, fruits, and other river fish (like tambaqui, which are plentiful). Selling directly to regional buyers in Manaus is prohibitive without the larger boats.

significant risk of spoilage. Consequently, this option is less profitable and is used when middlemen do not visit. It is more common for smaller communities that middlemen visit less frequently. We will find (see Table 4) that just over half of the fish in the control are sold to middlemen. Second, note the seven-fold difference between the price received by fishermen in the communities and the price received by “local fish processors.”

The communities in Mamirauá and Uacari capture only about one sixth of the overall value created by the pirarucu they catch and only about 30% of the fish’s pre-processed value. The sizable gaps between upstream and downstream prices in Figure 1 are not themselves evidence of market failure, however, and accusations against middlemen are not always justified. Indeed, middlemen can play vital roles in economies, especially in remote areas, by connecting distribution channels, making risky investments, taking on price risk, and establishing new markets. Although gaps between purchase and sales price may be substantial, they may reflect high costs and risk, and competition and free entry can bid rents down to zero. We therefore review contextual evidence of collusive behavior as well as the cost structure and profitability of middlemen in the market.

We begin with contextual evidence of collusive behavior. The market is organized annually at the Tefe Pirarucu Business Meeting (held annually in June/July, i.e., directly before the pirarucu fishing season begins in late August) brings together the eight *frigorificos* located in Manaus, and 8-10 viable middlemen operators with appropriate cold storage transportation boats in Mamirauá and 6 middlemen for Uacari. (Tefe itself is a small city located intermediate between the closer markets and Manaus.) The middlemen do not live in the river communities, but rather urban areas, including Manaus.

During this annual meeting, through the negotiation between the *frigorificos* and the middlemen, target prices per pirarucu kilogram are established for the fishing season, both the prices middlemen will pay fishing communities and the price they will receive from frigorificos in Manaus.⁴ Based on Tefe municipal records, these meetings have been held annually since 2004.

Hundreds of river communities in Mamirauá and Uacari sell their pirarucu to this limited number of middlemen. The river is divided up amongst the middlemen by custom (and distance so middlemen take a cluster of communities) so that two middlemen rarely go to the same river community’s dock. At present, no contract or other type of guarantee governs

⁴To the knowledge of the staff of the local NGO, Foundation for Amazonas Sustainability, no representatives of the fishing communities have been invited or been able to participate in this annual pre-fishing season meeting.

the communities' sale of pirarucu to middlemen. The middlemen pay the communities either in cash or leave behind a promissory note. The middlemen only earn their money after they land the pirarucu in Manaus and complete the sale to the frigorificos. Many river communities relay experiences of how the middlemen do not always return to the river communities later in the year to settle their debts for the previous fishing season.

Next we review the profitability of middlemen. Table A.1 in Appendix A includes an estimated basic income statement for the middleman carrying pirarucu from Mamirauá reserve to markets in larger cities like Manaus.⁵ The total cost per kilogram of pirarucu delivered is R\$1.03, inclusive of labor (captain and crew), in-kind labor compensation (i.e., meals), fuel, ice, and cost of capital. Figure 1 and our data indicate the price paid by middlemen at the community dock was R\$3.5-\$3.6 per kilogram of pirarucu. Thus, their total costs are roughly R\$4.63 per kilogram. The middlemen can sell the pirarucu to regional buyers (in Tefe or Fonte Boa) for R\$8.5 per kilogram and to buyers in Manaus for R\$12. This price range is therefore enough to cover their costs two to three times over. There are of course logistical risks, but for pirarucu in the Manaus markets, there remains very little downside pricing risk for the middlemen, as the price for kilogram has remained constant at R\$11-13 for the fishing seasons of 2016-2021.

A natural question is why entry does not drive profits down. Perhaps middlemen require a combination of intensely local knowledge and capital that is simply rare. Moreover, potential contracting issues may prevent separate parties from coming together with local knowledge and capital, respectively. We view the results of the intervention below as evidence that entry is indeed profitable.

2.3 Intervention

Our NGO is partner, Fundacao Amazonas Sustentavel (FAS)—the leading environmental non-governmental organization in Brazil—focuses on the sustainable economic development of both the Amazon's natural resources and its river communities. Through its health, education, infrastructure, environmental conservation, and income generation programs, FAS serves 9,430 families (39,460 people) living in 16 protected reserves in the State of Amazonas. Since 2008, its flagship La Bolsa Floresta program, sponsored by the Fundo Amazonia, Bradesco Bank, and the State of Amazonas, pays a modest subsidy of R\$50/month to

⁵The analysis is based on research of the consultants from the University of Notre Dame's Mendoza College of Business as part of the collaboration explained below.

households in river communities who promise to care for the forest in an attempt to “make the forest worth more standing than clearing.”

In 2017-2018, FAS collaborated with the University of Notre Dame’s Mendoza College of Business to conduct a thorough examination of the opportunities presented by the existing pirarucu market structure. Based on this analysis, FAS decided to support further income generation of river communities through investment in larger transport boats. These investments in boats would improve access for pirarucu fishermen to regional markets. Starting in early 2018, through a collaborative process based on workshops with the communities, FAS first organized Mamirauá and Uacari fishermen into associations of 8-10 communities and then supported them in the acquisition of boats. These FAS boats would carry the communities’ pirarucu to regional market towns such as Fonte Boa (in Mamirauá) and Carauari (in Uacari) rather than depending on middlemen. La Bolsa Floresta Program financed the purchase of the FAS boats and FAS staff time and expenses. FAS Supervisor, Edvaldo Correa de Oliveira described the challenge:

Before the FAS boats, the communities were held ‘hostage’ to the middlemen. There have been times when a community has agreed with the middlemen to arrive on their docks on a particular day in November when they pre-negotiated a price for R\$4.5 or R\$5 per kilogram of pirarucu. When the middleman arrives, he only offers them R\$3.5 per kilogram. The communities have no ice, no storage, no transportation, and thus, no choice but to sell at the lower dictated price.

Improving the Amazon fishermen’s access to local and regional markets was FAS’s main objective, with the most significant investment in larger transport boats. However, reducing dependence on the middlemen’s cartel also required two further initiatives: first, coordination with municipal leaders for permissions to create outdoor markets for the sale of pirarucu during the fishing season (August-November, 2018); and second, investment in cold storage facilities in Fonte Boa and Manaus to enable pirarucu sales to customers during peak demand 4-5 months after the fishing season during Holy Week in the Spring of 2019. As outlined in Figure 1 of the Pirarucu Supply Chain, the fishermen could expect higher prices per kilogram of pirarucu as they moved down the value chain beyond the middlemen, to sell to local buyers and regional buyers.

However, this overall intervention to improve market access in a single fishing season also presented risks. These risks included the uncertainties of new channels (their own boats), selling to new customers in regional markets with whom they had no relationships

yet (rather than existing middlemen); and new delayed timing of payment (upon sale of pirarucu 4-5 months after the fishing season). Given these combined risks, one could expect poor fishing communities to engage in risk mitigating strategies, such as continuing to sell a portion of their pirarucu through the existing channels of known middlemen. During the first year of the intervention, fishing communities could also be expected to build relationships with local and regional buyers of pirarucu and develop approaches for pirarucu sales in March/April during Holy Week. And thus, as communities gain experience of these novel changes in market access, it could be expected that fishing communities would shift more of their pirarucu sales toward high priced channels and customers in subsequent years. The first fishing season of these combined changes in market access could reasonably be thought of as the floor of the possible impact of the intervention, with increases in prices and household income in future fishing seasons.

The intervention has an element of a one-year natural experiment in the way that some communities received boats and others were delayed by one year. The Mamirauá and Uacari community associations, supported by FAS, contracted with sellers in Manaus, Tefe, and Fonte Boa for 8 boats for the 8 Mamirauá associations and 1 boat for the Uacari association. All 9 boats were ordered at the same time. However, as of the start of the pirarucu fishing season in August 2018, only 6 of the 8 boats were delivered to the Mamirauá associations.⁶ Both of the remaining 2 Mamirauá sectors did receive their boats in time for the following year's (2019) pirarucu fishing season. The failure to deliver these boats on time in effect created a source of novel variation in Mamirauá. In our sample, 18 communities could transport their catch on their FAS boats to sell in regional markets, while 14 communities with no access to a FAS boat for the 2018 pirarucu fishing season were forced to continue their existing practices of selling to the middlemen. In Uacari, the late arrival of the FAS boat from the shipwright seller in the 2018 pirarucu fishing season created a circumstance in which the 8 Uacari communities in our sample transported their pirarucu to regional markets with the FAS boat in 2018, while the other 4 communities did not.⁷ Like in Mamirauá, all sectors in Uacari did receive a boat in time for the 2019 fishing season. We evaluate the

⁶More specifically, when the boat was delivered to one of the Mamirauá associations, its electrical and other systems on board were not functioning properly. The communities refused to take receipt of their boat until those systems were fixed. The seller agreed to the repairs. Furthermore, a second Mamirauá association did not receive its ordered boat due to a backlog at the boat builder.

⁷In Uacari, the Amazonas state government arbitrarily decided that only communities in the state (non-federal) reserves should have a FAS boat in 2018, while all communities in both state and federal reserves would have the FAS boat in 2019.

extent to which there were pre-existing differences or trends in our balance tests of the next section.

3 Empirical Analysis

To evaluate the effects of the boats, we combine our own household and key informant surveys collected in 2018 with secondary data from FAS, the Mamirauá Institute, and Associacao dos Produtores Rurais de Carauai (ASPROC). Both the Mamirauá Institute and ASPROC are environmental research institutes in the Amazon. After checking for balance on community baseline characteristics, we proceed with the assumption of conditional exogeneity of boat assignment, and we estimate impact regressions to evaluate the effect of the boat on household income and consumption as well as the pirarucu prices, quantity, and revenue attained at the community level.

3.1 Data

Our sample consists of 308 households across 44 communities, of which 26 receive a boat in time for the 2018 fishing season (the treatment group). Of the 308 households surveyed, 194 live in treated communities. We rely on a natural rather than controlled experiment, and so we did not conceive this experiment *ex ante*. We therefore lack baseline survey data, an important limitation. However, we combine several data sources *ex post*, following the allocation of the boat treatment during the 2018 season, to establish the conditional exogeneity of boat receipt and to estimate the impact of the boat treatment on household financial outcomes and community pirarucu sales. Our empirical analysis relies on a household and key informant survey (an interview with the community fishing leader) conducted in late 2018, following the 2018 fishing season when some communities received boats on time while others did not; phone calls to fishing leaders to retrospectively collect information about the 2017 fishing season; operational records from our NGO partner, FAS; a community-level survey collected by FAS prior to the 2018 fishing season; and historical fishing levels documented by environmental research institutes in the Amazon between 2013 and 2017 for some communities in our sample. Because the natural experiment created unexpected variation that we utilize *ex post*, these data on historical fishing levels for some communities in our sample are the only true panel data that we are able to access for this study. The decision to collect primary data via a household and key informant survey of the

community fishing leader takes place after we realize the variation in the timing of boat delivery, essentially enabling us to collect primary data in a single endline survey wave while establishing pre-intervention balance with secondary data sources. We provide a detailed description of each data source and its use in the Data Appendix (Appendix B).

Together, the household and key informant surveys, both reflecting the post-2018 harvest season, provide information on our outcomes of interest. The household surveys compose our only data source at the individual-level and contain information on family income, consumption, time use, and travel. The key informant survey of the community fishing leader contains information on the community’s 2018 pirarucu catch and revenue. We construct household income in 2018 as the total annual income recorded by households in the 2018 household survey plus the average income per household earned if the community sold pirarucu to FAS, which FAS then sold during the 2019 Holy Week, a time of high demand for pirarucu.⁸ From the key informant surveys, we construct the pirarucu price accessed by the community, based on the reported pirarucu quantity and revenue that the community achieved during the 2018 harvest.

The rest of our data sources are used to assess pre-intervention balance and test for any preexisting differences in fishing trends. In late 2019 and early 2020, we contact the community fishing leaders via phone to collect information about the 2017 pirarucu catch and revenue.⁹ We use FAS’ operational records to collect information about community population, remoteness in terms of distance to the closest market, and eligibility for the Bolsa Floresta social assistance program. We use a community-level survey conducted by FAS prior to 2018 on access to health and education infrastructure, such as whether a community has a school and employs health workers, to understand pre-intervention sociodemographic characteristics in our sample. Finally, we use longitudinal data on

⁸We collect incremental income from the FAS 2019 Holy Week Fair, which reflects income earned from fish caught during the 2018 pirarucu season. The pirarucu harvest occurs once per year and so we calculate annual income, inclusive of the incremental income from the fair, and then divide by 12 to produce average monthly income. However, we were not able to repeat this data collection for the 2019 pirarucu harvest. As all communities had received boats for the 2019 fishing season, we planned non-experimental data collection as a follow-up. Because much of the income of the 2019 season is realized in the Holy Week of 2020, data collection unfortunately had to be abandoned when Manaus was one of the hardest hit cities in Brazil with the COVID-19 pandemic.

⁹We learn from FAS that many of the fishing leaders retain strong records or recollections of recent years’ pirarucu harvests, so we initiate this data collection exercise in the hope of acquiring data on pirarucu quantity and revenue in 2017, the pre-intervention harvest season. Unfortunately, this effort was also cut short by the COVID-19 pandemic, which hit the Brazilian Amazon especially hard. We are able to reach 28 of the 44 community fishing leaders.

historical fishing levels, from the Mamirauá Institute and ASPROC, environmental research institutes in the Amazon, to test for preexisting differences in fishing trends. These historical fishing levels are documented at the sector-level and are available for four of the eight sectors in our sample.¹⁰

Table A.2 in Appendix A contains summary statistics on our household sample. The respondents are predominantly male (65%) and middle-aged (average age is about 40), with low education levels. Only 31% of the respondents have completed primary school. They are also heavily engaged in fishing (85% of the sample) and farming (78% of the sample). Two-thirds are eligible for FAS' flagship social assistance program, La Bolsa Floresta, indicating that they tend to be quite poor and engaged in livelihoods that FAS deems important for the Amazon's environmental sustainability. Because our household survey data consist of a single cross-section collected after the intervention, we summarize any potentially time-variant characteristics across the control group only ($N = 114$). Among the control group, the average monthly income is R\$670 (or about 180 USD).¹¹ Average monthly spending on food amounts to 65% of household income, or R\$435. Only 35% of control respondents own a radio, and only 54% own a cell phone. Households allocate about 30 hours per week to fishing and 20 hours per week to farming. They typically make 17 trips to a nearby city per year and just under one-half of the sample report regular travel to a distant city.

3.2 Balance

The variation in our data does not come from a randomized experiment. Hence, it is particularly important to assess pre-intervention balance, comparing time-invariant and pre-2018 characteristics between communities that received boats as expected in 2018 and those that did not. In general, balance is good: we detect no statistically significant differences between treatment and control communities on the number of households per community, eligibility for Bolsa Floresta, distance to market, presence of a school, number of teachers, presence of health agents, number of health agents, presence of a water ambulance, or access to water treatment (Table 1).

Given the balance, we can use these data as descriptive statistics of our communities. On average, communities in our sample are home to 17-18 households, and about 80% of

¹⁰Sectors represent the associations of communities through which boats were purchased.

¹¹This assumes an exchange rate of R\$3.7 = 1 USD at the time of the survey in October/November 2018.

the communities contain households who are eligible for La Bolsa Floresta. Communities are quite remote – the closest market is typically about 10 hours away by boat (in many communities, travel time is a better indicator of effective remoteness than distance as it reflects differences in currents and transportation infrastructure). About 80-90% of communities have their own school, and there are typically 2-5 teachers per community (0.11-0.26 teachers per household) and 1-2 health agents per community (0.04-0.09 health agents per household). About 20% of the communities in our sample have access to a water ambulance, and about 80% have access to water treatment.¹²

We do, however, find one important difference in our data, though this is not out of line with what one would expect to find even if treatment were randomized. Among the community fishing leaders from whom we were able to collect information retrospectively about the 2017 harvest season, we find that treatment communities harvested a greater quantity of pirarucu in 2017 relative to control communities (significant at the 5% level). Given this finding, we control for pre-treatment differences in pirarucu levels. Because pirarucu quantity is an outcome of interest itself, we also examine whether there is a difference in trend between treatment and control communities using historical fishing levels between 2013 and 2017. We find no evidence that this is the case.¹³ We show that the pirarucu harvest in sectors that receive a boat does not change differentially over time relative to sectors that do not receive a boat (Table A.3 in Appendix A).

In sum, given the results on balance, we proceed with an assumption of exogeneity of treatment, conditional on a set of household and community controls explained below.

3.3 Impact on Households

We estimate OLS regressions to measure the impact of the boat on household income, consumption, travel to market centers, and time allocation. We specify the following

¹²We sometimes have missing values in community characteristics, if FAS did not collect data from a given community in their health and education survey. We separately test whether the rate of missing data varies differentially between treatment and control communities and find no evidence that this is the case.

¹³The average fishing level in 2017 reflected in this time series analysis does not perfectly correspond with the average fishing level in 2017 reflected in Table 1, our balance table, because each relies on a different data source. The balance table reports fishing levels in 2017 from retrospective phone calls to fishing leaders in 28 of 44 communities (reflecting both sectors in Uacari and 7 of 8 sectors in Mamirauá) while the time series on fishing levels comes from environmental records, which were only available for 4 of the 8 sectors in Mamirauá. While the incompleteness of these data is not ideal, it reflects the challenge of collecting information in a region as remote as the Brazilian Amazon, especially during the COVID-19 pandemic, when the region was hit especially hard. To our knowledge, we are the first people to access and compile data to this extent on a supply chain in the Amazonas.

equation for each household i in community c in reserve r :

$$Y_{icr} = \beta boat_c + \delta X_i + \gamma X_c + \lambda_r + \varepsilon_{icr} \quad (1)$$

In this model, β is the coefficient of interest, measuring the impact of the boat, allocated at the community level, on household outcome Y_{icr} . We control for household characteristics X_i , which include the number of household members, and community characteristics X_c , which include travel time (in hours) to the closest market and its square (“remoteness controls”), and the interactions of these remoteness controls with the reserve $r \in \{\text{Mamirauá, Uacari}\}$. Following our results on balance, we include the quantity of pirarucu harvested by the community in 2017 as a control.¹⁴ We also include reserve fixed effects, λ_r . Additionally, we winsorize household data to the 5th and 95th percentiles and cluster standard errors at the community level. We also report randomization inference p-values in brackets below clustered standard errors, given that the optimal level of clustering is unclear. Decisions about fishing and sales are made at the community level, but boats were purchased at the sector level. In contrast to standard errors clustered at the community level, the randomization inference p-values are based on the 10 community groups that ordered boats (6 sectors in the Mamirauá reserve and 1 sector in the Uacari reserve that received boats on time, and 2 sectors in Mamirauá and 1 sector in Uacari that did not). Our discussion of results below assumes the precision indicated by clustered standard errors.

We find that the boat results in a statistically significant and sizable increase in household income (Table 2). Households in communities with a boat experience a 27% increase in income, an additional R\$184 per month on the control mean of R\$670 per month (significant at a 5% level). We find an effect of similar magnitude on monthly consumption, R\$148, a 17% increase, though this estimate is not significant at conventional levels. We further disaggregate the components of consumption into spending on food, gas, diesel, and transport. We find that the boat results in higher monthly spending on food and gas. Households in communities with a boat spend an additional R\$68 on food each month, relative to the control mean of R\$435, a 16% increase (significant at a 5% level). This increased food expenditure accounts for roughly half of the observed increase in total consumption. Households with a boat also spend an additional R\$42 on gas, relative to the

¹⁴To maintain a constant sample, we equate missing values in a community’s 2017 pirarucu quantity to the mean, and we include a flag to indicate that the value was missing in a given community. The quantity of pirarucu harvested in 2017 is not missing differentially between treatment and control.

control mean of R\$200, a 21% increase (significant at a 10% level). Gas is used both for cooking and as a boat lubricant. This suggests that households in communities with a boat spend a substantial portion of the incremental income on direct food consumption and its associated costs, perhaps substituting from less preferred to more preferred food goods.¹⁵

We find a small, negative and imprecise effect of the boat on diesel spending, which is predominantly used as a fuel for motor boats. We see suggestive evidence that households spend more on transport to market centers (above fuel costs). We estimate that households in communities with a boat spend an additional R\$38 per month on transport, relative to a control mean of R\$152, a 25% increase (not significant at conventional levels). This is consistent with our finding that households in a community with a boat are 16 percentage points more likely to travel to distant cities (significant at a 5% level). Travel to distant cities may encompass both personal and business travel, so a positive change on this dimension is not necessarily indicative of a direct effect in which households are more likely to travel to market themselves and sell pirarucu directly to the consumer, bypassing the middlemen. The increase in travel to distant cities, thus, is best interpreted as a measure of welfare in which households gain broad access to goods, services, and markets to which they did not have prior connection.

Importantly, we find no statistically significant effect of the boat on households' allocation of labor hours to fishing and farming. The estimated effects on hours allocated to fishing and farming are not only imprecise but also small and slightly negative (Table A.4 in Appendix A). Assuming that the chief impact of the boat is on market access and not labor productivity, this may suggest that higher incomes are not realized through a quantity channel, which is consistent with our community level analysis of the pirarucu market in the next section.

3.4 Impact on the Pirarucu Market

To measure the effect of the boat on prices attained, quantity sold, and revenue earned by the community, we estimate the following OLS regression for each community c in reserve r :

$$Y_{cr} = \beta boat_c + \gamma X_c + \lambda_r + \varepsilon_{cr} \quad (2)$$

¹⁵We find that households in communities with a boat are more likely to purchase fish and canned food, which may be preferred goods.

Similar to Equation 1, β is the coefficient of interest, measuring the impact of the boat on community outcome Y_{cr} . We control for community characteristics X_c , which include travel time (in hours) to the closest market and its square (“remoteness controls”), the interactions of these remoteness controls with the reserve $r \in \{\text{Mamirauá, Uacari}\}$, the quantity of pirarucu harvested by the community in 2017, and the number of households in the community, if the outcome is not already reported per household.¹⁶ We also include reserve fixed effects, λ_r . When estimating the effect of the boat on 2018 prices, we additionally control for 2017 prices. Like in the household results, we report randomization inference p-values based on 10 community groups in brackets below heteroskedasticity-robust standard errors.

We find a striking impact of the boats on the price received for pirarucu (Table 3). Communities with a boat obtain nearly 20% higher prices for their pirarucu, an additional R\$0.77 per kilogram of pirarucu on the control mean of R\$4 per kilogram (significant at the 5% level). This may be driven in part by greater bargaining power with the middlemen: we find that communities are able to negotiate 25% higher prices from the middlemen, raising the cartel price from 3.6 R\$/kg to 4.5 R\$/kg (not significant at conventional levels; p-value = 0.13). Consistent with the narrative put forth by FAS, this suggests that communities are no longer “hostage” to the middlemen’s prices, as they now have the ability to store and transport their own product to market and thus a higher outside option. Given the final pre-processing price of R\$12/kg paid by *frigorificos*, this amounts to the portion of pre-processing value captured by the fishermen rising from approximately 30% to 40%. We find an imprecise negative impact of the boat on the number of middlemen with whom communities deal, perhaps indicating that communities either sell to other types of buyers or deal with fewer middlemen because they are able to negotiate a higher price more quickly.

In Table 4, we show the effect of the boat on quantity and revenue from pirarucu sales. We find a near zero but imprecise effect of the boat on the total quantity of pirarucu per household: 45 kg/household on a control mean of 1,100 kg/household (not statistically significant).¹⁷ Assuming a single pirarucu weighs 75 kg, this amounts to an effect of less than 1 additional fish per household. The lack of an effect on total quantity is consistent with the lack of labor reallocation towards fishing. This may also be consistent with a

¹⁶Like in the household level specification, we equate missing values in a community’s 2017 pirarucu quantity to the mean, and we include a flag to indicate that the value was missing in a given community.

¹⁷Pirarucu is harvested at the community level, but we normalize per household to adjust for any differences in community size.

community view that leaving the once endangered pirarucu in the Amazon is an investment of sorts – savings for the future. We see a larger, but still imprecise, effect on the quantity of pirarucu sold specifically to middlemen. We estimate that communities with a boat sell 32% more pirarucu to middlemen than communities without a boat, an effect of 200 kg/household on a control mean of 620 kg/household (not statistically significant). Given the much smaller effect on total quantity, this may suggest that communities are actually substituting sales to non-middlemen with sales to middlemen. This is consistent with an indirect effect: communities with a boat have greater bargaining power and so they increase relative sales to middlemen, versus other types of buyers, now that they can insist on a higher price. From the middlemen’s perspective, an increase in the quantity purchased by middlemen when prices increase exogenously from new outside option (i.e., a move up the monopsonist’s perceived upward sloping supply curve) would be at least theoretically consistent with the evidence of monopsony power among middlemen discussed in Section 2. From the fishing community’s perspective, continued use of middlemen may also reflect an attempt to hedge risk by maintaining relationships with pre-existing buyers. As communities build relationships with other customers in market towns, they may shift more pirarucu sales towards these higher priced channels in future years.

We find larger, but still imprecise, effects of the boat on revenue from pirarucu, both in total and from sales to middlemen (Table 4). Communities increase revenue per household by R\$1,500 on a control mean of R\$4,300, a 35% increase (not statistically significant). They increase revenue from middlemen by R\$1,700 per household on a control mean of R\$2,100, an 80% increase (not statistically significant). These point estimates are imprecisely measured, but the magnitudes are in line with the significant income estimate in the household estimates: the point estimates on pirarucu revenue at the community level account for about two-thirds of the estimated increase in monthly household income.¹⁸ These point estimates also suggest that the increase in prices of R\$0.77 per kilogram mechanically accounts for 60% of the R\$1,500 increase in pirarucu revenue.¹⁹

¹⁸The R\$1,500 estimate of community fishing revenue in Table 4 is annual, whereas the household income effect of R\$184 in Table 2 is monthly, yielding an annual increase of roughly R\$2,200. A 95% confidence interval around the revenue point estimate easily encompasses R\$2,200, and so we interpret any difference between the increase in annual household income and the increase in annual pirarucu revenue per household as statistical noise.

¹⁹Based on results from Table 3, this is produced by multiplying R\$0.77/kg (the price premium that communities with a boat earn) and 1,119 kg (the mean quantity of pirarucu sold in the control, i.e., assuming the intervention has no effect on the total quantity of pirarucu fished). Of this, the indirect effect (i.e., the increased revenues from middlemen sales due to a rise in their price) is sizable. Using control sales

Given our imprecision, we cannot rule out sizable positive impacts on quantities. However, together with the household estimates on time allocation, the results paint a picture in which the effect on total revenue is driven by higher prices rather than increases in the total quantity sold. Meanwhile, the effect on revenue from middlemen seems likely driven by a combination of an ability to negotiate a higher price from the middlemen and therefore selling more to the middlemen.

In sum, the presence of the boat enables communities to earn a higher price on their pirarucu. Communities do not appear to fish more, either in terms of time allocated towards fishing or quantity of pirarucu harvested, and so increases in revenue seem to result predominantly from higher prices. This translates to an increase in household income, which communities primarily spend on food and gas, and greater travel to distant cities.

3.5 Cost-Benefit Analysis

The question of the return on investment associated with economic development programs can frequently prove thorny. In this particular experience, however, the diligent data gathering of FAS staff can provide insights. Let us examine the return on investment for an average FAS boat of approximately 10-15 tons, transporting pirarucu in Mamirauá. It cost about R\$150,000 and serves an association of 8-10 communities. Our research on the 2018 pirarucu fishing season indicates that each household with access to a FAS boat earned R\$184 in incremental monthly income as compared to control communities with no access to FAS boats. Since communities average 17-18 households per community, the total annual gain in income of R\$38,000+ per community, for an annual increase in revenue that exceeds the capital expense. However, operational expenses are considerable, and subtracting away operational costs for the FAS boats in terms of gas, diesel, and ice, the payback period on the FAS boat investment solely from pirarucu fishing is estimated just under three years. It is not unprecedented for boats on the Amazon to continue working twenty years. Moreover, FAS boats are used during the offseason to transport basic goods and people which provides additional benefits to the communities.

Given the increased income for communities fishing pirarucu, this development policy could productively be extended to the Amana and Piagaucu-Purus Reserves which would

to middlemen (622 kg/household) and multiplying by the middleman price increase of R\$0.9/kg yields R\$560, while using the higher treatment sales (826 kg/household) yields R\$743. Thus, the indirect effect mechanically would account for 37%-50% of the total increase in revenue. These calculations should be taken suggestively, given the lack of precision of our point estimates.

impact thousands of additional fishing households. Both reserves have extensive lakes with pirarucu and experienced fishermen. Potential acquisition of FAS boats would enable these communities to bypass regional middlemen and transport their pirarucu from Amana to the regional center of Tefe and from Piagaucu-Purus to Manaus markets.

4 Model

In the previous section we showed strong effects on income from a cooperative intervention to bypass middlemen. Now we rationalize this finding in a model where the market power of middlemen endogenously determines the prices received by communities for their fish. Our dynamic model has simple mechanics that build on earlier work by [Banerjee and Newman \(1993\)](#) and [Ghatak and Jiang \(2002\)](#). We show that the market power of middlemen can create a poverty trap, which would not exist if markets were competitive. Moreover, we show that a cooperative intervention that resembles the one studied in this paper can eliminate the poverty trap. Furthermore, we show that the response of the middlemen may be critical to escaping the poverty trap.

4.1 Fishing Communities

We begin by formally stating the problem of a representative community that sells fish to outside markets. Communities produce a fixed quantity of fish every period. They make decisions over how much of the fish they consume within the community and how much they sell outside the community. Selling fish allows communities to purchase other goods, and to save money for the subsequent period. They choose where to sell the fish. They may either sell to middlemen or they may make a discrete investment to operate a boat. Operating a boat is costly, but allows them to bypass the middlemen and sell at a higher price directly in outside markets.

The community begins each period t with wealth w_t . Each period, communities catch Q units of perishable fish. They can sell their fish to a middleman at a price p_t , or they can transport the fish directly to the market where they will earn a price p^* . They may only sell directly in the market if they pay a fixed cost I to operate a boat, which must be paid at the beginning of the period. Communities do not have access to external financing, so they can only operate a boat if their wealth w_t is greater than I . The number of units of fish that may be brought to market by a purchased boat in each period is q . For simplicity, we

model the boat as only lasting a single period.

Communities have preferences over consumption c_t and assets transferred to next period, b_t .²⁰ Assets include both savings, which earns a constant interest rate r , and the value of boats, which may be used to transport fish. Their utility function takes the form:

$$u_t = (1 - s) \ln c_t + s \ln b_t.$$

The consumption good c_t is an aggregate of the quantity of fish consumed f_t and the quantity of other goods purchased using the proceeds from the sale of fish, o_t . The aggregation of these goods into the consumption good is given by:

$$c_t = (1 - \phi) f_t^\alpha + \phi o_t,$$

where $\alpha < 1$ indicates diminishing returns to fish.²¹ The extent to which communities value other goods relative to fish is captured by the parameter ϕ .

We denote the discrete choice to operate a boat as $\chi_t \in \{0, 1\}$. We choose o_t to be the numeraire good, so the community's problem is written as:

$$\max_{\{\chi_t, c_t, b_t, f_t, o_t\}} (1 - s) \ln c_t + s \ln b_t$$

subject to

$$o_t + b_t + p_t f_t \leq (1+r)w_t + \bar{x} + \min\{q, Q\}(\chi_t p^* + (1 - \chi_t) p_t) + (Q - \min\{q, Q\}) p_t - \chi_t r I \equiv y_t, \quad (3)$$

$$\chi_t I \leq w_t, \quad (4)$$

$$c_t = (1 - \phi) f_t^\alpha + \phi o_t, \quad (5)$$

$$\chi_t \in \{0, 1\}. \quad (6)$$

The first inequality is the budget constraint, which requires that expenditures not exceed their funds. Their funds come from wealth w_t , a lump sum payment the household receives each period \bar{x} , and income from fishing. If they decide to employ the boat, that means the

²⁰Modeling utility in each period as a function of consumption and savings follows [Banerjee and Newman \(1993\)](#). Relative to modeling utility over an infinite sequence of consumption choices, this greatly simplifies the analysis and allows us to easily characterize dynamics.

²¹In Footnote 3, we noted that the fish consumed and fish sold are different species of fish, but since both are the output of fishing activities, we ignore that distinction here for simplicity.

assets used in the acquisition of the boat were not saved, so the return on those assets (equal to rI) are foregone by choosing to employ the boat.²² Therefore, the boat is only profitable if the interested earnings from the boat exceed the return on savings those funds.²³ The second inequality requires that investment in the boat must be financed from existing wealth. The third constraint is the definition of the consumption good, and the fourth specifies that the decision to operate a boat is discrete. We denote available resources, which depend on endogenous decisions, wealth and prices, as y_t . Then the first-order conditions of this problem imply consumption and savings given by:

$$o_t + p_t f_t = (1 - s) y_t, \quad (7)$$

$$b_t = s y_t. \quad (8)$$

Moreover, as long as $o_t > 0$, the demand for fish is given by:

$$f_t = \left(\frac{(1 - \phi) \alpha}{\phi p_t} \right)^{1/(1-\alpha)},$$

which is conveniently independent of wealth.²⁴ Dynamics in the model follow from the fact that asset savings in period t become the assets in period $t + 1$:

$$w_{t+1} = b_t.$$

We assume that $s(1 + r) < 1$, so that the dynamic model has a steady-state wealth level.

²²In our notation, the timing is as follows. First, households enter the period with w units of assets and first decide whether or not to operate a boat using I units, and earn r on the $w - I$ remaining assets. Second, all production occurs and income from both assets and fishing are realized by households. Third, all purchases are made and consumption occurs.

²³For simplicity, we assume there is a market for boats, so a community can always buy or sell their boat for I at the beginning of each period.

²⁴This is a result of our assumption of quasi-linear preferences. For low levels of income, $o_t = 0$ and $f_t = (1 - s)y_t/p_t$. This occurs when:

$$y_t < \frac{p_t^{-\alpha/(1-\alpha)}}{1 - s} \left(\frac{(1 - \phi) \alpha}{\phi} \right)^{1/(1-\alpha)}$$

4.2 Wealth Dynamics

We now characterize the dynamics of the wealth process and show that monopsonistic middlemen pricing gives rise to a poverty trap. If a community has sufficiently high initial wealth, they are able to operate a boat and receive greater earnings in each period. Those with lower initial wealth are unable to operate a boat, have lower earnings and save less. We provide conditions under which this gives rise to two different steady state wealth levels, and a cutoff in initial wealth that determines which steady state the community eventually realizes. Those communities below the initial wealth cutoff and transitioning toward the low steady state level of wealth are those experiencing the poverty trap.

Consider two cases for the relationship between the market price p^* and the price offered by the middlemen p_t , which are both taken as given by the community. Here we focus on the case where parameters are such that communities would like to sell more than one boat full of fish.²⁵

If $p_t \geq p^* - \frac{I}{q}$, purchasing and operating their own boat is not better for the community than selling to the middlemen. This would arise, for example, if middlemen have a (weakly) better transportation technology than that available to the community. In this case, no boat is operated by the community ($\chi_t = 0$ and $y_t = w_t + \bar{x} + p_t Q$), so that $w_{t+1} = s((1+r)w_t + \bar{x} + p_t Q)$. In this case there is no poverty trap as there is only one steady state level of wealth, which is given by:

$$\bar{w}(p_t) = \frac{s(\bar{x} + p_t Q)}{1 - s(1+r)}. \quad (9)$$

If $p_t < p^* - \frac{I}{q}$, the boat offers greater net income to the community, so they will purchase it if their wealth is great enough. In this case, $y_t = w_t + (p^* - p_t)q - I + p_t Q$ if the community purchases the boat, and $y_t = w_t + p_t Q$ otherwise. The law of motion for wealth is therefore:

$$w_{t+1} = \begin{cases} s((1+r)w_t + (p^* - p_t)q - I + p_t Q) & \text{if } w_t > I \\ s((1+r)w_t + p_t Q) & \text{otherwise.} \end{cases}$$

The lower and upper branches of the law of motion lead to different possible steady

²⁵The assumption allows for the community to always face the middlemen price of selling on the margin. Formally, here we are assuming that:

$$Q - q > \left(\frac{(1-\phi)\alpha}{\phi p_t} \right)^{1/(1-\alpha)}.$$

states $\bar{w}_0(p_t)$ and $\bar{w}_1(p_t)$, with:

$$\bar{w}_0(p_t) = \frac{s(\bar{x} + p_t Q)}{1 - s(1 + r)}, \quad (10)$$

$$\bar{w}_1(p_t) = \frac{s(\bar{x} + (p_t^* - p_t)q - I + p_t Q)}{1 - s(1 + r)}. \quad (11)$$

Clearly, $\bar{w}_1(p_t) > \bar{w}_0(p_t)$. Which of these potential steady states is realized in the long run depends on I . If $I > \bar{w}_1(p_t) > \bar{w}_0(p_t)$, the boat will ultimately be unaffordable, since, for any initial wealth level, eventually $w_t < I$. The only steady state wealth level is $\bar{w}_0(p_t)$. Likewise, if $\bar{w}_1(p_t) > \bar{w}_0(p_t) > I$, the boat will be ultimately affordable, since eventually $w_t > I$ for any initial wealth level. In that case, the only steady state is $\bar{w}_1(p_t)$. In these cases, in the long run communities never operate boats or always operate boats, respectively.

There is a third possibility, which we are most interested in. If $\bar{w}_1(p_t) > I > \bar{w}_0(p_t)$ then poverty traps are possible. In this case, initial wealth determines which steady state is achieved. If a community has initial wealth of at least I they transition to the higher steady state level $\bar{w}_1(p_t)$. If their initial wealth is below I they transition to the lower wealth level $\bar{w}_0(p_t)$. The existence of these two separate steady states depends on the prices offered by middlemen being sufficiently low. We plot an example of this in the first panel of Figure 2. In the next subsection we show how market power by middlemen can depress the prices they offer.

4.3 Middlemen

The previous section showed prices offered by middlemen are crucial for wealth dynamics. In order to understand the relationship between the boats and the prices offered by middlemen, we now consider the problem of the middlemen directly. We consider the case where the middlemen live for one period and operate as a cartel. The middlemen take the final market price p^* as given and use the same boat technology as the communities to bring the fish to market. Hence, they face a marginal cost of c to transport the fish. We assume that $c = rI/q$ so that both middlemen and communities have available the same transportation technology.

The cartel of middlemen acts as a monopsonist in purchasing fish from the community. That is, the cartel offers a take-it-or-leave-it price to the community, and the community then decides how much fish to sell to the middlemen at that price. The supply of fish that the middlemen face from a community S_χ depends on whether the community operates a

boat or not. Community supply without a boat is:

$$S_0(p) = Q - \left(\frac{(1-\phi)\alpha}{\phi p} \right)^{1/(1-\alpha)}$$

The supply for a community with a boat is:

$$S_1(p) = Q - q - \left(\frac{(1-\phi)\alpha}{\phi p} \right)^{1/(1-\alpha)}$$

The profit maximization problem for a middleman:

$$\max_{p_t} S_\chi(p) (p^* - p - c)$$

which yields the following first-order condition:

$$\frac{\frac{1}{1-\alpha} \left(\frac{(1-\phi)\alpha}{\phi} \right)^{1/(1-\alpha)} p^{(\alpha-2)/(1-\alpha)}}{S_\chi(p)} = \frac{1}{(p^* - p - c)}.$$

The left-hand side (the percentage loss in supply from a marginal increase in price) is decreasing in the price, since both the exponent on price is negative and supply of fish in the denominator is increasing in price. In contrast, the right-hand side (the percentage increase in markup) is increasing in price, approaching infinity as the price approaches the competitive price of $p^* - c$. A set of appropriate parameter restrictions assures an interior solution satisfying our assumptions.²⁶

²⁶The right-hand side defines an upper bound on the middlemen price, since it goes to infinity as the middlemen price approaches the competitive price, $p_t = p^* - c$. Recall that we assumed that the supply of fish was bounded below by $S(p_t) = Q - f_t > q$, so that some fish are sold to middlemen regardless of whether a boat is purchased. In order to ensure this, we need to set parameters to have a lower bound on prices that ensures that. The possible prices are therefore bounded above and below

$$\left(\frac{(1-\phi)\alpha}{\phi(Q-q)} \right) < p_t < p^* - c$$

We can find the parameters necessary to ensure this price, by plugging in for equality into the above optimality condition and setting the left hand side greater than the right-hand side. Manipulating gives us the following necessary assumption on parameters:

$$\frac{\alpha}{\alpha-1} \left(\frac{\phi}{(1-\phi)} \right) (Q-q)^{(2-\alpha)/(1-\alpha)} \left(p^* - c - \left(\frac{(1-\phi)\alpha}{\phi(Q-q)} \right) \right) > q.$$

Since the left-hand side is a product of positive terms and p_t^* can be arbitrarily large in principle, the

The optimal middlemen price p_χ depends on whether or not the community has a boat because it depends on the supply function, $S_\chi(p)$. Notice that the supply of fish to middlemen is always smaller with the boat at any given price, $S_1(p) < S_0(p)$. Consequently, $p_1 > p_0$. Hence, an additional indirect benefit of the boat is a higher middlemen price, which leads to the following wealth dynamics:

$$w_{t+1} = \begin{cases} s((1+r)w_t + \bar{x} + (p^* - p_1)q - rI + p_1Q) & \text{if } w_t > I \\ s((1+r)w_t + \bar{x} + p_0Q) & \text{otherwise.} \end{cases} \quad (12)$$

The upper and lower branches of the law of motion again lead to two different steady states, $\bar{w}_1 = \frac{s(\bar{x} + (p^* - p_1)q - rI + p_1Q)}{1 - s(1+r)} > \frac{s(\bar{x} + p_0Q)}{1 - s(1+r)} = \bar{w}_0$, but now the difference between them is greater than if they faced a common price. The dynamics of this poverty trap is illustrated in the second panel of Figure 2.

To understand the role that competition plays in this analysis, it is useful to compare this to the case where the cartel is eliminated and middlemen are competitive. In the competitive case, middlemen are only able to charge a price that allows them to break even. At a constant marginal cost rI/q , the competitive middlemen price would be $p = p^* - rI/q$ for all communities. As discussed in the previous subsection, at those prices the poverty trap is eliminated. Hence, the poverty trap in this model can only exist because of the market power of the middlemen.

4.4 Interventions to Escape Poverty Trap

Here we consider two types of interventions in the model that are motivated by the intervention considered in previous sections. The intervention implemented by FAS in Brazil had effects that can be interpreted in the model.

First, the FAS intervention can be interpreted in the model as implicit credit. By agreeing to participate in the boat program, communities agree to forego the Bolsa Floresta payments they usually receive from FAS for the period of time needed to pay for the boat (approximately three years). FAS is the sole holder of the source of repayment (the future payments), and, in any case, these remote communities would not have been able to receive such a large loan from other sources. Just as cooperation allows communities to share the high cost of the boat across communities, credit allows individual communities to break the

existence of parameter values satisfying this assumption is assured.

cost over time, thus eliminating the poverty trap.

This aspect is interpreted in the model as simply moving money from the time when income is realized to the time when it is needed for investment by allowing units to be shifted from \bar{x} to w_t . Since w_t is required to finance the boat in equation (4), if enough funds can be moved forward in time this could eliminate the poverty trap entirely. This allows for communities initially in a poverty trap with $\bar{w}_0 < I$ to escape if $\bar{w}_0 + \bar{x} \geq I$. However, for an individual community it could be that their own income \bar{x} over the duration of the loan is simply not large enough.

The second way to interpret the FAS intervention in the model is as encouraging *cooperation* among communities, which allows them to share a boat. Although a single community may lack the assets needed to acquire a boat (or return needed to justify it), it may be feasible (and profitable) for a group of communities to jointly purchase one. However, in the absence of means of committing to agreements among communities they may be unwilling to do so. Because FAS operates programs that help communities, including providing them with the Bolsa Floresta payments as part of their participation in their programs, FAS is able to enforce these agreements. Indeed, each group of communities that shares a boat under this program from FAS signs a contract regarding the use and maintenance of each boat, which is overseen by FAS. It is unclear how this type of agreement could be reached or enforced in the absence of this intervention.²⁷

In the model, we implement this aspect of the intervention by allowing the case where two communities can share a single boat (each using half of its capacity and bearing half the cost), and show that this can also break the poverty trap. We use the results from the previous subsection, and show that even partial use of the boat has a direct benefit of higher achieved prices on part of the fish harvest, and also an important indirect benefit of achieving higher prices from the middlemen. This helps them to achieve a higher steady state wealth level and may even cause them to achieve the highest steady state wealth level where each of the two communities is eventually wealthy enough to afford their own boat.

Suppose two communities both initially have wealth \bar{w}_0 , the steady state level from the poverty trap in the previous case. Now suppose that $\bar{w}_0 > I/2$, and they now have the option of sharing the costs and benefits of operating a boat. That is, each spends $I/2$ to operate the boat each period and can use the boat to sell $q/2$ units of fish in the market.

²⁷In addition, FAS assists communities find customers for pirarucu sales through fairs.

Now the cartel of middlemen faces a supply function from these communities of:

$$S_{0.5}(p) = Q - \frac{q}{2} - \left(\frac{(1-\phi)\alpha}{\phi p} \right)^{1/(1-\alpha)}.$$

As in the previous subsection, facing this supply function the cartel then solves for an optimal price $p_{0.5}$, where $p_0 < p_{0.5} < p_1$. Now a complete description of wealth dynamics is given by:

$$w_{t+1} = \begin{cases} s((1+r)w_t + \bar{x} + (p^* - p_1)q - I + p_1Q) & \text{if } w_t > I \\ s((1+r)w_t + \bar{x} + (p^* - p_{0.5})\frac{q}{2} - \frac{I}{2} + p_{0.5}Q) & \text{if } I > w_t > I/2 \\ s((1+r)w_t + \bar{x} + p_0Q) & \text{otherwise.} \end{cases} \quad (13)$$

We can now define a potential steady state based on the middle branch given by:

$$\bar{w}_{0.5} = \frac{s((p^* - p_{0.5})\frac{q}{2} - \frac{I}{2} + p_{0.5}Q + \bar{x})}{1 - s(1+r)}. \quad (14)$$

Clearly, this is an improvement on the initial wealth level for two reasons. First, $q/2$ units of fish are sold at market prices, and $p^* > p_0$. Second, middlemen respond to the change in supply that the boat causes so that $p_{0.5} > p_0$, even for the fish not shipped on the boats. Therefore, this in itself is an improvement that would not be available in the absence of cooperation. Moreover, if $\bar{w}_{0.5} > I$ then in a finite number of periods, wealth exceeds I and each community can operate its own boat. This means that the steady state achieved by the communities will not be $\bar{w}_{0.5}$ but \bar{w}_1 , the highest steady state wealth achieved in the previous case. Again, because of both of the direct gains (better price at the market for shipped goods) and indirect gains (better middlemen prices), there is a range of parameter values such that $\bar{w}_0 < I < \bar{w}_{0.5}$. This implies that the cooperative strategy alone could help an otherwise poor community escape the poverty trap entirely. Moreover, for parameter values such that I is only slightly less than $\bar{w}_{0.5}$, the indirect pricing *response* of the middlemen to the boat may be crucial to escaping the trap. This is illustrated in the third panel of Figure 2.

Taken together, these interventions allow for communities initially in a poverty trap with $\bar{w}_0 < I$ to overcome it either by sharing the cost of the boat with cooperation, or by increasing available assets with credit. Given the high cost of these boats and relatively small community sizes, we believe that both aspects played an important role.

4.5 Is there a poverty trap?

Further mapping the model to the Amazonas environment, a poverty trap could exist if the cost of a boat were prohibitively high in a single year for a single community. Although in the model two communities share a boat, we have already noted that in reality the boats are shared by 8-10 communities. So, what if one community attempted to purchase it, without credit?

From Table 2, the average income per household is about R\$670 per household per month. With an average of 18 households per community, the overall annual income of a river community is approximately R\$145,000. The average cost of a sufficiently large boat, with the necessary hold constructed to carry ice, is approximately R\$150,000. Without access to credit, a community would need to dedicate more than a full year's income for a single year to a boat purchase, essentially implying that the community would not consume food, gas, or diesel during that time. The high level of consumption relative to income in Table 2 implies that communities live close to subsistence, further underscoring the implausibility of such a purchase.

Would the additional income in a single year make this possible? Table 3 shows the effects on market pricing, including an increase from R\$4/kilogram to R\$4.77 for those communities with access to boats, nearly a 20% price improvement. If we assume that communities were somehow able to access this higher price, that is, that they were not subject to the lower price implied by the middlemen's market power, then average community income would increase by R\$15,500 (1,119 kg/household x 18 households/community x R\$0.77/kg) to R\$160,000. The river community would be closer to the purchase of a boat, but it would still not be financially possible at current fishing levels. Without a huge expansion in fishing, which is limited by the conservation needs of preserving the pirarucu numbers, one would need a community many times larger than the average to enable such an investment. The groups that purchased boats consisted of 8-10 communities — implying 144-180 households on average. The largest community in our sample is just 46 households, much smaller than this.

5 Conclusion

We have presented results in which an NGO-initiated and community-financed boat purchase enables households to attain higher prices on harvested fish and subsequently increase their

incomes. Using variation that came from the inability to supply boats to all communities simultaneously, we identified the causal impact of the intervention. The intervention led to a substantial increase in income for these poor communities and directly impacted welfare through an increase in consumption. Our strongest results showed that these benefits came from higher prices received for their fish from the end market, but we also showed results of effects from the upward response of prices from middlemen. We find that the boats are cost-effective, paying for themselves within 3 years. Working alone, however, the cost of the boat would be prohibitive for any individual community. We presented a model that showed how both higher market prices and the responses of middlemen could be pivotal in enabling communities to escape man-made poverty traps that the lack of wealth for boats otherwise constitutes.

The results are important. Typical approaches for reaching remote communities (large scale infrastructure) are expensive, so alternatives such as boats and bridges ([Brooks and Donovan, 2020](#)) may be an important tool for policymakers. This is especially true in remote areas of developing countries where it is difficult to implement larger scale projects.

Our paper suggests several avenues for future research. First, in our setting we plan to conduct a long-term follow-up to evaluate how the use of the boats changes over time, how additional moneys are spent and invested, and how increased integration affects community engagement with outside areas, such as external labor markets and educational opportunities. Second, the results suggest that cooperative investments were profitable. This may indicate that other investments for reaching communities may also be profitable, and more research is needed to understand why investments may not be made. Further investigating the collusive nature of supply chains, such as the one we examined, is a first step towards designing the policies that will improve the welfare of remote communities.

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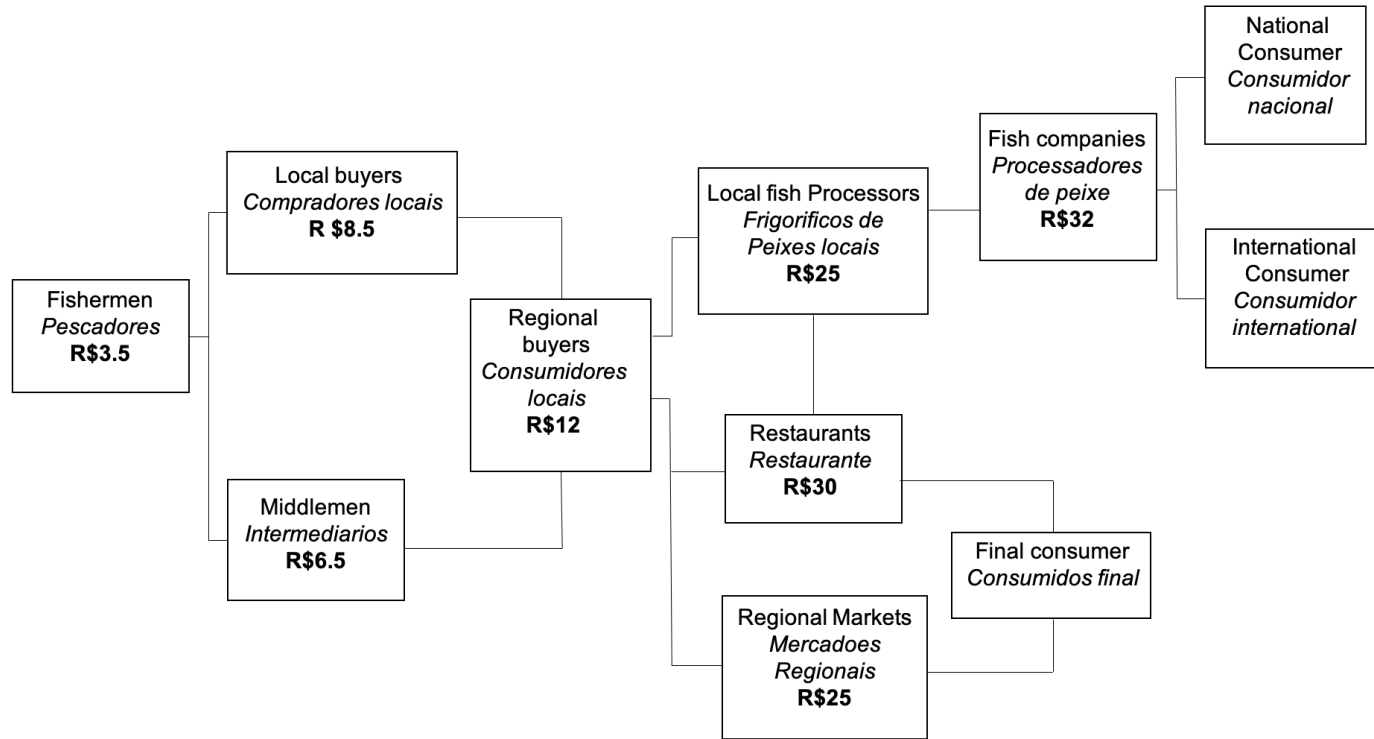
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Figures

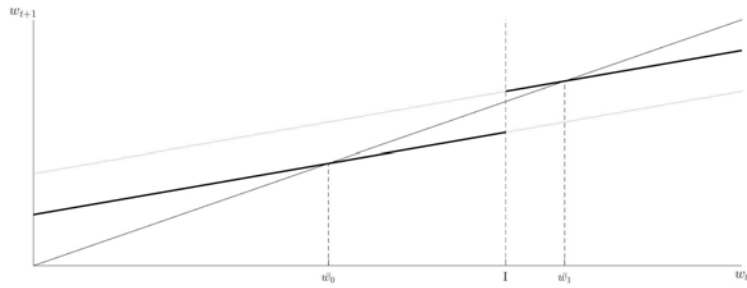
Figure 1: Pirarucu Supply Chain and Market (Reais/kg) in Mamiraua, Amazonas, 2018



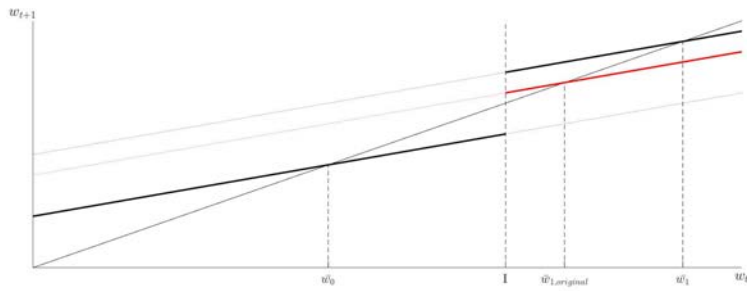
Source: Mamiraua Institute with own analysis

Figure 2: Wealth Dynamics Under Monopsonistic Middlemen Pricing

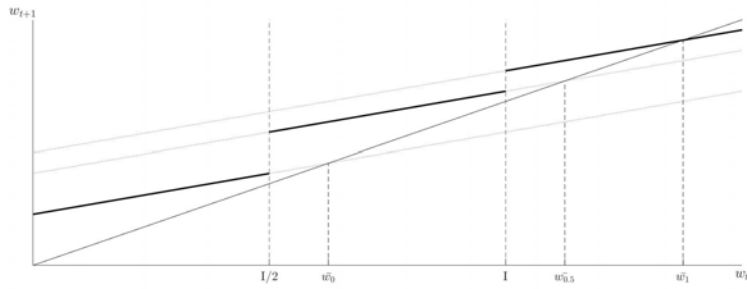
Panel 1: Poverty trap at low middleman price



Panel 2: Boat enabling higher middleman price and higher steady state wealth



Panel 3: Cooperative investment eliminating poverty trap



Tables

Table 1: Balance on Baseline Community Characteristics

	Boat in 2018	N	No boat in 2018	N	Diff	(s.e.)	P-value
<i>Panel A: Collected from NGO's operational records</i>							
num households	18	26	17	18	1	(3.6)	0.78
eligible for Bolsa Floresta = 1	.81	26	.78	18	.03	(.13)	0.81
hrs to closest market	11	26	9.6	18	1.8	(4.8)	0.71
<i>Panel B: Collected retrospectively from fishing leaders</i>							
num pirarucu 2017	229	18	65	10	164**	(78)	0.05
<i>Panel C: Collected from NGO's community survey</i>							
has school = 1	.95	21	.82	17	.13	(.1)	0.21
num teachers per hh	.11	21	.26	17	-.16	(.11)	0.18
has health agents = 1	.57	21	.53	17	.042	(.17)	0.80
num health agents per hh	.035	21	.092	17	-.056	(.054)	0.30
has ambulance = 1	.19	21	.18	17	.014	(.13)	0.91
has water treatment = 1	.75	20	.82	17	-.074	(.14)	0.60

Notes: Standard errors estimated in a t test on the equality of means between the communities receiving a boat in 2018 and the communities without a boat in 2018. * $p < 0.1$, ** $p < .05$, *** $p < 0.01$

Table 2: Effects on Households

	Components of consumption:						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
	income	consum	food	gas	diesel	transport	distant city travel = 1
FAS boat 2018	184** (72) [.22]	148 (92) [.32]	68** (32) [.19]	42* (22) [.28]	-6.5 (14) [.85]	38 (28) [.22]	.16** (.069) [.38]
Control Mean	670	892	435	200	42	152	.47
R ²	.044	.17	.14	.37	.12	.092	.27
Observations	308	308	308	308	308	308	308

Notes: In parentheses, we report standard errors clustered at the community level. In square brackets, we report randomization inference p-values based on 10 community groups. Outcomes (1)-(6) are monthly in 2018 Brazilian Reais, R\$. Consumption is the sum of food, gas, diesel, and transport spending. Outliers winsorized to the 5th and 95th percentile. All specifications include reserve fixed effects and the following controls: the number of pirarucu harvested in 2017, household size, time to market and its square, the interaction of time to market with reserve, and the interaction of time to market squared with reserve. Missing values in control variables set to mean, and missing value flag included as covariate. Asterisks denote statistical significance under clustered standard errors: *** 1%, ** 5%, * 10%.

Table 3: Effects on Market Pricing and Channel (Community Level)

	(1) R\$/kg all	(2) R\$/kg mid	(3) num middlemen
FAS boat 2018	.77** (.34) [.28]	.9 (.56) [.24]	-2.1 (2.8) [.43]
Control Mean	4	3.6	5.6
R ²	.38	.47	.12
Observations	41	32	43

Notes: In parentheses, we report heteroskedasticity robust standard errors. In square brackets, we report randomization inference p-values based on 10 community groups. **All** reflects annual sales to any buyer. **Mid** reflects annual sales solely to middlemen. Sample in columns (1) and (2) consists of those communities reporting positive quantity sold to any buyer (1) or to middlemen (2). All specifications include reserve fixed effects and the following controls: the number of pirarucu harvested in 2017, the number of households residing in the community, time to market and its square, the interaction of time to market with reserve, and the interaction of time to market squared with reserve. Columns (1)-(2) additionally including the pirarucu price in 2017 as a control. Missing values in control variables set to mean, and missing value flag included as covariate. Asterisks denote statistical significance under robust standard errors: *** 1%, ** 5%, * 10%.

Table 4: Effects on Quantity Sold and Revenue Earned by Communities

	(1)	(2)	(3)	(4)
	kg/hh	kg/hh	R\$/hh	R\$/hh
	all	mid	all	mid
FAS boat 2018	45	204	1,486	1,734
	(275)	(307)	(1,491)	(1,531)
	[.86]	[.4]	[.55]	[.22]
Control Mean	1,119	622	4,314	2,145
R ²	.32	.29	.25	.22
Observations	41	41	41	41

Notes: In parentheses, we report heteroskedasticity robust standard errors. In square brackets, we report randomization inference p-values based on 10 community groups. **All** reflects annual sales to any buyer. **Mid** reflects annual sales solely to middlemen. All specifications include reserve fixed effects and the following controls: the number of pirarucu harvested in 2017, time to market and its square, the interaction of time to market with reserve, and the interaction of time to market squared with reserve. Missing values in control variables set to mean, and missing value flag included as covariate. Asterisks denote statistical significance under robust standard errors: *** 1%, ** 5%, * 10%.

A Main Appendix

Table A.1: Sailing Boats from Mamirauá to Market
Variable Transportation Costs

	Unit Cost (R\$)	Unit	Quantity	Cost (R\$)
Fuel	5	Per liter	4,000	20,000
Ice	0.30	Per kilogram	30,000	9,000
Meals	20	Per day	12	240
Deck hand labor	254.50	Per person	2	509
Captain's labor	509	Per person	1	509
Boat depreciation	556	Per trip	1	556
Total cost per trip:				R\$30,814
Average kg of fish transported per trip :				30,000 kg
Average variable transportation cost per kg of fish:				R\$1.03/kg

Source: Qualitative interviews conducted by the University of Notre Dame's Mendoza College of Business with middlemen.

Table A.2: Summary Statistics for the 2018 Household Survey

	mean	sd
<i>Characteristics fixed prior to treatment, full sample (N = 308)</i>		
female = 1	.35	.48
age	39	13
hh size	5.4	2.5
born in community = 1	.42	.49
completed primary school = 1	.31	.46
hh receives Bolsa Floresta = 1	.67	.47
fisherman = 1	.85	.36
farmer = 1	.78	.42
livestock herder = 1	.16	.36
<i>Potentially time-variant characteristics, control group (N=114)</i>		
monthly income, R\$	670	482
monthly food spending, R\$	435	251
monthly transport spending, R\$	152	164
owns radio = 1	.35	.48
owns cell phone = 1	.54	.5
fishing hours/week	29	25
farming hours/week	18	15
annual trips to nearby city	17	15
travels to a distant city = 1	.47	.5

Table A.3: Testing for Differential Pre-Trends in Fishing Levels
2013-2017, Mamirauá

	(1)	(2)
	ln fish	ln fish
year*boat	.034 (.82)	.034 (.84)
year	.014 (.73)	
Year FE's	No	Yes
R ²	.032	.079
Observations	18	18

Notes: In parentheses, we report wild cluster bootstrap p-values, given the small number of sectors composing the sample. The unit of observation is the sector-year. **Year** denotes a yearly time trend. All specifications include sector FE's. The outcome is the natural log of the sector's total fish harvest in a given year.

Table A.4: Effects on Household Time Allocation

	(1) fishing hrs/week	(2) farming hrs/week
FAS boat 2018	-0.6 (4.1) [.92]	-1.8 (2.3) [.23]
Control Mean	29	18
R ²	.041	.1
Observations	308	308

Notes: In parentheses, we report standard errors clustered at the community level. In square brackets, we report randomization inference p-values based on 10 community groups. All specifications include reserve fixed effects and the following controls: the number of pirarucu harvested in 2017, household size, time to market and its square, the interaction of time to market with reserve, and the interaction of time to market squared with reserve. Missing values in control variables set to mean, and missing value flag included as covariate. Asterisks denote statistical significance under clustered standard errors: *** 1%, ** 5%, * 10%.

B Data Appendix

Our empirical analysis utilizes a combination of several primary and secondary data sources:

Primary data sources:

1. A household survey conducted between October and November 2018, following the 2018 pirarucu harvest, that collects household-level information on demographics, finances, labor allocation, and travel.
2. A key informant survey with the fishing leader in each community, collected at the same time as the household survey, which documents community-level pirarucu quantity, revenue, and access to intermediaries during the 2018 fishing season.
3. Phone calls to fishing leaders to retrospectively collect information about pirarucu quantity and revenue during the 2017 fishing season.

Secondary data sources:

4. Operational records from our NGO partner, FAS, to collect community-level information on the size, remoteness, and Bolsa Floresta eligibility of the communities in our sample at the time of the intervention. FAS operational records also allow us to attribute any income earned from the 2019 Holy Week pirarucu fairs, which sold pirarucu that were harvested during the 2018 season, back to the respective communities that contributed fish to be sold at the fair.
5. A community-level survey collected by FAS prior to 2018, which surveyed the leader of most communities in our sample about access to education and health infrastructure.
6. Historical records from the Mamirauá Institute and ASPROC, environmental research organizations in the Amazon, on fishing levels leading up to 2018. The Mamirauá Institute and ASPROC document this information at a sector-level, i.e., at the level of the associations formed between communities to purchase boats.

Our qualitative analysis and description of the setting in Section 2 relies on qualitative interviews conducted by the University of Notre Dame’s Mendoza College of Business with fishermen, municipal leaders, pirarucu customers, middlemen, frigorificos, and staff at our NGO partner, Foundation for Amazonas Sustainability, across Manaus and the Mamiraua and Uacari reserves.