Big Fish in Thin Markets: Competing with the Middlemen to Increase Market Access in the Amazon*

Viva Ona Bartkus† Wyatt Brooks‡ Joseph P. Kaboski§ Carolyn Pelnik¶

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Abstract

Middlemen are ubiquitous in supply chains. They connect remote communities to end markets but often have 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 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 can create a poverty trap, and cooperative investment can help eliminate the poverty trap.

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†University of Notre Dame. Email: vbartkus@nd.edu
‡Arizona State University. Email: wyatt.brooks@asu.edu
§University of Notre Dame, BREAD, and NBER. Corresponding author. Email: jkaboski@nd.edu
¶Tufts University. Email: carolyn.pelnik@tufts.edu

1 Introduction

The geographic concentration of both economic activity and poverty are well know 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 remotest settings of 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 considerably 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.

To evaluate the intervention, we combine surveys we implemented 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 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

[1] For 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).

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.

Our impact results involve household-specific effects on 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, which is a 20 percent increase in price (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.

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 an artificial 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 sellers 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.

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, 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.

2 Background on the Brazil Amazon and Experiment

We study whether 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

[2] In 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.

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.

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 perhaps ten or so 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 seven 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.

The small, fragmented, and isolated nature of the Amazon communities combined with the perishable nature of the product reinforces their weak bargaining position; in essence, the middlemen dictate the price per kilogram at the community's dock. As a consequence, the communities in Mamirauá and Uacari capture roughly one sixth of the overall value created by the pirarucu they catch and only about one third of the fish's pre-processed value. Figure 1 displays the prices in terms of reais/kilogram (R$/kg) for each step of the pirarucu value chain in Mamirauá.

As the leading environmental non-governmental organization in Brazil, Fundacao Amazonas Sustentavel (FAS) focuses on 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 households in river communities who promise to care for the forest in an attempt to "make the forest worth more standing than clearing."

2.2 Intervention

In 2017-2018, FAS collaborated with a major American university 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 one boat for the Uacari association. All 8 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.[3] 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.[4] Like in Mamirauá, all sectors in Uacari did receive a boat in time for the 2019 fishing season. We evaluate the 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 historical administrative data from FAS and the Mamirauá Institute, an NGO and research institute working towards sustainable development 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]More 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.

[4]In 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.

3.1 Data

The key informant surveys and administrative data contain information at the community and sector levels, in contrast to the individual level household surveys.[5] Surveys of key informants, typically the head of community fishing association, are used to gather information on total catches, fishing income, and prices, since fishing operations are shared by the community and done collectively. We also use the key informant survey to collect common community-level data, such as distances to public services. Household surveys contain data on other non-fishing income, consumption, time use, and travel. We allocate fishing income (from the community key informant surveys) proportionately to households. Administrative data contains information about historical fishing levels as well as non-fishing information on access to public services. We use this administrative data to evaluate pre-intervention balance and test for any pre-existing differences in fishing trends.

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 collect survey data on these 308 households in October and November 2018, following the 2018 pirarucu harvest. Table A.1 in the Appendix contains summary statistics on our household survey respondents. They 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).[6] 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.

[5] Sectors represent the associations of communities through which boats were purchased.

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

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, number of teachers, 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 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). There are typically 1-2 teachers per community (0.08-0.12 teachers per household) and 1-3 health agents per community (0.06-0.15 health agents per household). About 30% of the communities in our sample have access to a water ambulance, and about 65% have access to water treatment.[7]

We do, however, find two important differences in our data, but these are not out of line with what one would expect to find even if treatment were randomized. We find that treatment communities harvested a greater quantity of pirarucu in 2017 relative to control communities (significant at the 5% level) and are marginally significantly more likely to have a school (significant at the 10% level). Given this finding, we control for pre-treatment differences in pirarucu levels, but 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 (pre-2018). We find no evidence that this is the case. Using administrative data reflecting the total pirarucu harvest at the sector level between 2013 and 2017, 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.2 in the Appendix). Additionally, we cannot reject the null hypothesis that the

[7] We sometimes have missing values in community characteristics, due to limitations in the administrative data that we are able to access. We separately test whether the rate of missing data varies differentially between treatment and control communities. Of the community characteristics in Table 1, the rate of missing is only statistically significantly different between treatment and control on one dimension: the variable indicating water ambulance access.

joint significance of the differential effect of being in the treatment group (relative to the control) on the pirarucu harvest is 0 in each of the years leading up to 2018 (Table A.3 in the Appendix).[8] We depict historical pirarucu fishing levels for both treatment and control sectors in Figure 2.

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

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

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 $r \in$ {Mamirauá, Uacari}. Following our results on balance, we include the quantity of pirarucu harvested by the community in 2017 as a control.[9] We also include reserve fixed effects, λ_r. Additionally, we winsorize househod data to the 5^{th} and 95^{th} percentiles and cluster standard errors at the community level.

We find that the boat results in a statistically significant and sizeable 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

[8] This excludes year 2016, for which we lack sufficient data to measure pirarucu levels. We have near complete data on the number of pirarucu harvested by 6 sectors in our sample for 2013, 2014, 2015, and 2017.

[9] To 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.

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 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.[10]

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).

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 the Appendix). 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:

$$Y_{cr} = \beta boat_c + \gamma X_c + \lambda_r + \varepsilon_{cr} \tag{2}$$

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

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

of these remoteness controls with the reserve $r \in$ {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.[11] We also include reserve fixed effects, λ_r. When estimating the effect of the boat on 2018 prices, we additionally control for 2017 prices.

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. 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).[12] 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 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 increasing relative sales to middlemen, versus other types of buyers, now that they can negotiate a

[11] Like 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.

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

higher price. We might expect that this reflects an initial response to the boats where communities hedge risk by continuing to sell to 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.[13] 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.

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

[13]The 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.

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 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 savings transferred to next period, b_t.[14] 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. 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:

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

[14]Modeling 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.

subject to

$$o_t + b_t + p_t f_t \leq \min\{q,Q\}\left(\chi_t p^* + (1-\chi_t)\, p_t\right) + \left(Q - \min\{q,Q\}\right) p_t + w_t - \chi_t I \equiv y_t, \tag{3}$$

$$\chi_t I \leq w_t, \tag{4}$$

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

$$\chi_t \in \{0,1\}. \tag{6}$$

The first inequality is the budget constraint, which requires that expenditures not exceed sources of income. 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:

$$o_t + p_t f_t = (1-s)\, y_t, \tag{7}$$

$$b_t = s y_t. \tag{8}$$

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.[15] Communities receive a constant rate of return r on their savings, so that wealth evolves according to:

$$w_{t+1} = (1+r)\, b_t.$$

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

[15] This 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.[16]

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 $y_t = w_t + p_t Q$), so that $w_{t+1} = s\left(1+r\right)\left(w_t + p_t Q\right)$. In this case there is no poverty trap as there is only one steady state level of wealth, which is given by:

$$\overline{w}(p_t) = \frac{s\left(1+r\right)p_t Q}{1 - s\left(1+r\right)}. \tag{9}$$

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, $y_t = w_t + \left(p^* - p_t\right)q - I + p_t Q$ if the community purchases the boat, and $y_t = w_t + p_t Q$ otherwise. The law of motion for wealth is therefore:

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

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

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

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

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

$$\overline{w}_0(p_t) = \frac{s(1+r)\,p_t Q}{1-s(1+r)}, \tag{10}$$

$$\overline{w}_1(p_t) = \frac{s(1+r)\left((p_t^* - p_t)\,q - I + p_t Q\right)}{1-s(1+r)}. \tag{11}$$

Clearly, $\overline{w}_1(p_t) > \overline{w}_0(p_t)$. Which of these potential steady states is realized in the long run depends on I. If $I > \overline{w}_1(p_t) > \overline{w}_0(p_t)$, the boat will ultimately be unaffordable, since, for any initial wealth level, eventually $w_t < I$. The only steady state wealth level is $\overline{w}_0(p_t)$. Likewise, if $\overline{w}_1(p_t) > \overline{w}_0(p_t) > I$, the boat will be ultimately affordable, since eventually $w_t > I$ for any initial wealth level. In that case, the only steady state is $\overline{w}_1(p_t)$. 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 $\overline{w}_1(p_t) > I > \overline{w}_0(p_t)$ 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 $\overline{w}_1(p_t)$. If their initial wealth is below I they transition to the lower wealth level $\overline{w}_0(p_t)$. The existence of these two separate steady states depends on the prices offered by middlemen being sufficiently low. 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 I/q to transport fish.

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:

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

The supply for a community with a boat is:

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

The profit maximization problem for a middleman:

$$\max_{p_t} S_\chi\left(p\right)\left(p^*-p-\frac{I}{q}\right)$$

which yields the following first-order condition:

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

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^*-I/q. A set of appropriate parameter restrictions assures an interior solution satisfying our assumptions.[17]

[17]The right-hand side defines an upper bound on the middlemen price, since it goes to infinity as the middlemen price approaches the competitive price, $p_t=p^*-I/q$. 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

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

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:

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

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:

$$w_{t+1} = \begin{cases} s\,(1+r)\,(w_t + (p^* - p_1)\,q - I + p_1 Q) & \text{if } w_t > I \\ s\,(1+r)\,(w_t + p_0 Q) & \text{otherwise.} \end{cases} \tag{12}$$

The upper and lower branches of the law of motion again lead to two different steady states, $\overline{w}_1 = \frac{s(1+r)((p^*-p_1)q-I+p_1Q)}{1-s(1+r)} > \frac{s(1+r)p_0Q}{1-s(1+r)} = \overline{w}_0$, but now the difference between them is greater than if they faced a common price.

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 I/q, the competitive middlemen price would be $p = p^* - I/q$ 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 Cooperative Intervention

Finally, we consider an intervention in the model that is motivated by the intervention considered in previous sections. We modify the model to allow 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 $\overline{w}_0$, the steady state level from the poverty trap in the previous case. Now suppose that $\overline{w}_0 > I/2$, and they now have the

Since the left-hand side is a product of positive terms and p_t^* can be arbitrarily large in principle, the existence of parameter values satisfying this assumption is assured.

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. 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:

$$w_{t+1} = \begin{cases} s(1+r)(w_t + (p^* - p_1)q - I + p_1 Q) & \text{if } w_t > I \\ s(1+r)\left(w_t + (p^* - p_{0.5})\frac{q}{2} - \frac{I}{2} + p_{0.5}Q\right) & \text{if } I > w_t > I/2 \\ s(1+r)(w_t + p_0 Q) & \text{otherwise.} \end{cases} \tag{13}$$

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

$$\overline{w}_{0.5} = \frac{s(1+r)\left((p^* - p_{0.5})\frac{q}{2} - \frac{I}{2} + p_{0.5}Q\right)}{1 - s(1+r)}. \tag{14}$$

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 $\overline{w}_{0.5} > I$ 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 $\overline{w}_{0.5}$ but $\overline{w}_1$, 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 $\overline{w}_0 < I < \overline{w}_{0.5}$. This implies that the cooperative strategy could help an otherwise poor community escape the poverty trap entirely. Moreover, for parameter values such that I is only slightly less than $\overline{w}_{0.5}$, the indirect pricing *response* of the middlemen to the boat may be crucial to escaping the trap.

5 Conclusion

We have presented results in which an NGO-initiated intervention enabled fishing communities to bypass middlemen through the cooperative, community-financed purchase of boats. 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 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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References

Aghion, P. and P. Bolton (1997): "A Theory of Trickle-Down Growth and Development," *Review of Economic Studies*, 64, 151–172.

Aker, J. C. (2010): "Information from markets near and far: Mobile phones and agricultural markets in Niger," *American Economic Journal: Applied Economics*, 2, 46–59.

Alder, S. and I. Kondo (2020): "Political Distortions and Infrastructure Networks in China: A Quantitative Spatial Equilibrium Analysis," *Working Paper*.

Asher, S. and P. Novosad (2020): "Rural Roads and Local Economic Development," *American Economic Review*, 110, 797–823.

Assunção, J., M. Lipscomb, A. Mobarak, and D. Szerman (2017): "Agricultural Productivity and Deforestation in Brazil," Working Paper.

Asturias, J., Manuel Garcia-Santana, and R. Ramos (2019): "Competition and the Welfare Gains from Transportation Infrastructure: Evidence from the Golden Quadrilateral in India," *Journal of the European Economic Association*, 17, 1881–1940.

Banerjee, A. V. and A. F. Newman (1993): "Occupational Choice and the Process of Development," *Journal of Political Economy*, 101, 274–298.

Brooks, W. and K. Donovan (2020): "Eliminating Uncertainty in Market Access: The Impact of New Bridges in Rural Nicaragua," *Econometrica*, 88, 1965–1997.

Burgess, R., R. Jedwab, E. Miguel, A. Morjaria, and G. Padró i Miquel (2015): "The value of democracy: evidence from road building in Kenya," *American Economic Review*, 105, 1817–51.

Donaldson, D. (2018): "Railroads of the Raj: Estimating the Impact of Transportation Infrastructure," *American Economic Review*, 108, 899–934.

Ghatak, M. and N.-H. Jiang (2002): "A simple model of inequality, occupational choice, and development," *Journal of Development Economics*, 69, 205–226.

Jedwab, R. and A. Storeygard (2020): "The average and heterogeneous effects of transportation investments: Evidence from Sub-Saharan Africa 1960-2010," Tech. rep., National Bureau of Economic Research.

Jensen, R. (2007): "The Digital Provide: Information (Technology), Market Performance, and Welfare in the South Indian Fisheries Sector," *Quarterly Journal of Economics*, 122, 879—-924.

Jensen, R. and N. Miller (2018): "Market Integration, Demand, and the Growth of Firms: Evidence from a Natural Experiment in India," *American Economic Review*, 108, 3583–3625.

Lu, W. J. (2020): "Transport, Infrastructure and Growth: Evidence from Chinese Firms," *Working Paper*.

Murphy, K. M., A. Shleifer, and R. W. Vishny (1989): "Industrialization and the Big Push," *Journal of Political Economy*, 97, 1003–1026.

Pfaff, A. (1999): "What Drives Deforestation in the Brazilian Amazon? Evidence from Satellite and Socioeconomic Data," *Journal of Environmental Economics and Management*, 37.

Piketty, T. (1997): "The Dynamics of the Wealth Distribution and the Interest Rate with Credit Rationing," *Review of Economic Studies*, 64, 173–189.

Sotelo, S. (2020): "Domestic Trade Frictions and Agriculture," *Journal of Political Economy*, 128, 2690–2738.

Van Leemput, E. (2016): "A Passage to India: Quantifying Internal and External Barriers to Trade," International Finance Discussion Papers 1185.

Figures

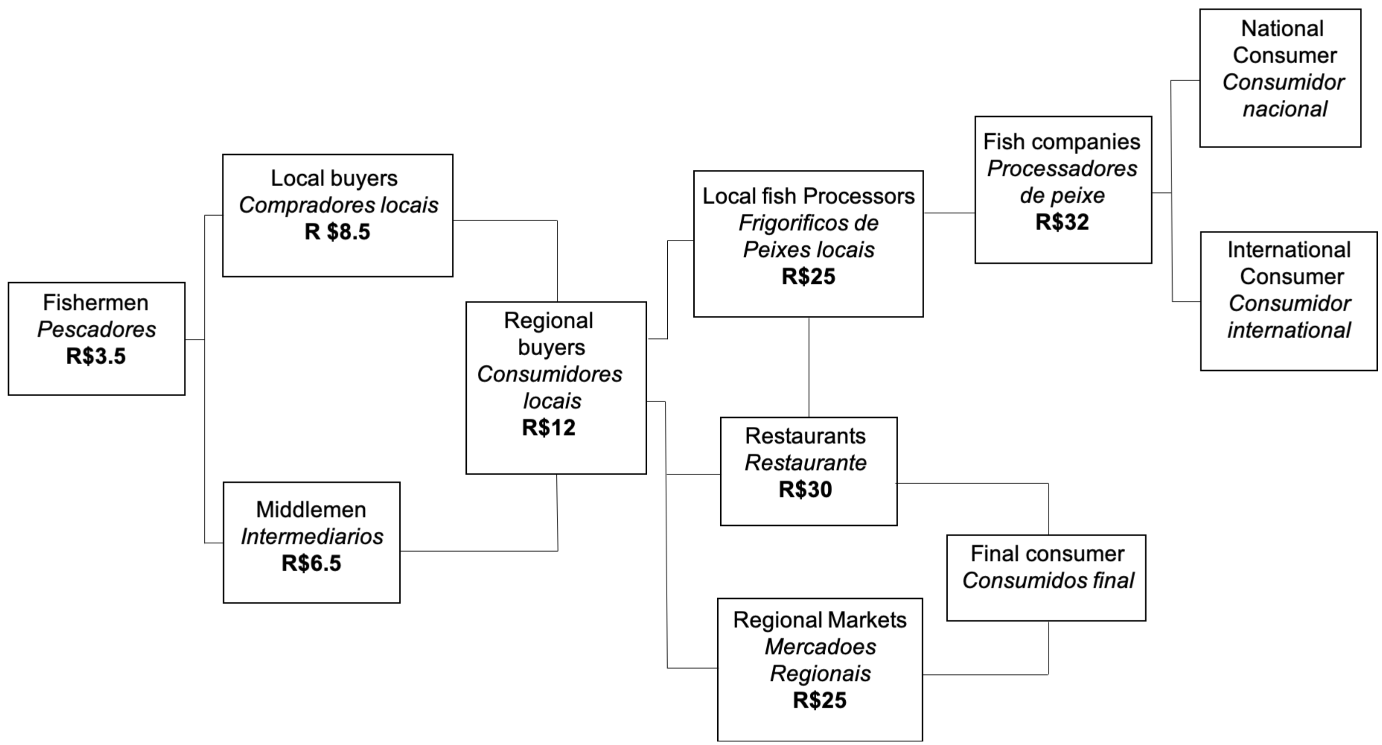

Figure 1: Pirarucu Supply Chain and Market (Reais/kg) in Mamiraua, Amazonas, 2018

Source: Mamiraua Institute with own analysis

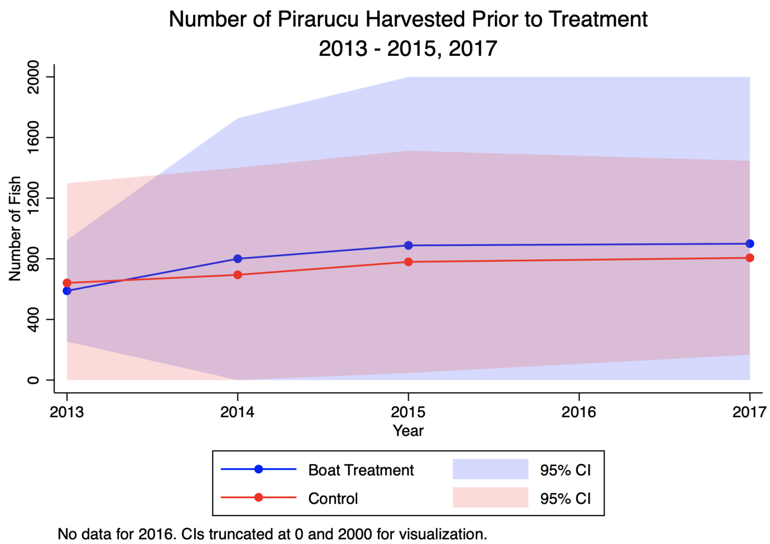

Figure 2: Historical Fishing Levels

Tables

Table 1: Balance on Baseline Community Characteristics

	Boat in 2018	N	No Boat in 2018	N	Diff	P-value
num households	18	26	17	18	1	0.78
eligible for Bolsa Floresta = 1	.81	26	.78	18	.03	0.81
hrs to closest market	11	26	9.6	18	1.8	0.71
num pirarucu 2017	229	18	65	10	164**	0.05
has school = 1	.9	20	.64	11	.26*	0.08
num teachers per hh	.12	20	.084	11	.039	0.25
has health agents = 1	.8	20	.55	11	.25	0.14
num health agents per hh	.056	20	.15	11	-.09	0.19
has ambulance = 1	.32	19	.29	7	.03	0.89
has water treatment = 1	.68	19	.64	11	.048	0.80

* $p < 0.1$, ** $p < .05$, *** $p < 0.01$

Table 2: Effects on Households

	(1) income	(2) consum	(3) food	(4) gas	(5) diesel	(6) transport	(7) distant city travel = 1
FAS boat 2018	184**	148	68**	42*	-6.5	38	.16**
	(72)	(92)	(32)	(22)	(14)	(28)	(.069)
num pira 2017	.048	.26	.15	.0048	.08*	-.061	-.00013
	(.15)	(.31)	(.15)	(.061)	(.045)	(.093)	(.00015)
hh size	13	43***	27***	5.2	1.9	.98	-.0063
	(11)	(11)	(5.9)	(3.1)	(1.5)	(4.4)	(.011)
Reserve FE's	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Distance controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Reserve*Distance	Yes	Yes	Yes	Yes	Yes	Yes	Yes
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

Standard errors clustered at the community level

Household data winsorized to the 5th and 95th percentiles

Outcomes (1) - (5) are monthly in 2018 Brazilian Reais, R$

Consumption is the sum of food, gas, diesel, and transport spending

Distance controls include time to market and its square

Missing values in control variables set to mean, and missing value flag included as covariate

* $p < 0.1$, ** $p < .05$, *** $p < 0.01$

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**	.9	-2.1
	(.34)	(.56)	(2.8)
num pira 2017	-.0026**	-.0038**	.0011
	(.0012)	(.0015)	(.0041)
pira price 2017	.23	.23	
	(.2)	(.17)	
num households	-.027*	-.033*	-.0085
	(.016)	(.017)	(.077)
Reserve FE's	Yes	Yes	Yes
Distance controls	Yes	Yes	Yes
Reserve*Distance	Yes	Yes	Yes
Control mean	4	3.6	5.6
R^2	.38	.47	.12
Observations	41	32	43

Robust standard errors in parentheses

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)

Distance controls include time to market and its square

Missing values in control variables set to mean

Missing value flag included as covariate

* $p < 0.1$, ** $p < .05$, *** $p < 0.01$

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

	(1) kg/hh all	(2) kg/hh mid	(3) R$/hh all	(4) R$/hh mid
FAS boat 2018	45	204	1,486	1,734
	(275)	(307)	(1,491)	(1,531)
num pira 2017	-.013	-.11	-4	-5.3
	(.95)	(1.1)	(5.6)	(5.8)
Reserve FE's	Yes	Yes	Yes	Yes
Distance controls	Yes	Yes	Yes	Yes
Reserve*Distance	Yes	Yes	Yes	Yes
Control mean	1,119	622	4,314	2,145
R^2	.32	.29	.25	.22
Observations	41	41	41	41

Robust standard errors in parentheses

All reflects annual sales to any buyer

Mid reflects annual sales solely to middlemen

Distance controls include time to market and its square

Missing values in control variables set to mean

Missing value flag included as covariate

* $p < 0.1$, ** $p < .05$, *** $p < 0.01$

A Appendix

Table A.1: Summary Statistics for the 2018 Household Survey

	mean	sd
Characteristics fixed prior to treatment, full sample (N = 308)		
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
Potentially time-variant characteristics, control group (N=114)		
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.2: Testing for Differential Pre-Trends

	ln fish
year*boat	-.03
	(.12)
year	.059
	(.047)
Sector FE's	Yes
Years included	2013 - 2015, 2017
R^2	.1
Observations	23

Standard errors clustered at the sector level

Outcome is natural log of sector pirarucu harvest

Each observation is a sector-year

Year denotes a yearly time trend

No data from 2016

* $p < 0.1$, ** $p < .05$, *** $p < 0.01$

Table A.3: Differential Effects of Treatment Assignment by Year

	(1) ln fish	(2) ln fish
year=2013 × boat=1	.074	.047
	(.47)	(.54)
year=2014 × boat=1	.24	.22
	(.76)	(.26)
year=2015 × boat=1	-.043	-.07
	(1.1)	(.23)
year=2017 × boat=1	.028	
	(.86)	
year=2014	.043	.029
	(.3)	(.22)
year=2015	.13	.13
	(.27)	(.26)
year=2017	.23	.23
	(.24)	(.23)
Constant	6.3***	6.3***
	(.41)	(.19)
Sector FE's	No	Yes
P-val: Joint sig of year*boat	.82	.49
R^2	.018	.15
Observations	23	23

Standard errors clustered at the sector level
Outcome is natural log of sector pirarucu harvest
Each observation is a sector-year
No data from 2016
* $p < 0.1$, ** $p < .05$, *** $p < 0.01$

Table A.4: Effects on Household Time Allocation

	(1) fishing hrs/week	(2) farming hrs/week
FAS boat 2018	-.6	-1.8
	(4.1)	(2.3)
num pira 2017	.0054	-.0071
	(.0095)	(.0057)
hh size	1.1*	.77**
	(.53)	(.36)
Reserve FE's	Yes	Yes
Distance controls	Yes	Yes
Reserve*Distance	Yes	Yes
Control mean	29	18
R^2	.041	.1
Observations	308	308

Standard errors clustered at the community level

Distance controls include time to market and its square

Missing values in control variables set to mean

Missing value flag included as covariate

* $p < 0.1$, ** $p < .05$, *** $p < 0.01$