Informal Contracts in an Incomplete Market: The Price of Milk in Paraguay *

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Abstract

The relative price of locally-produced milk and cheese in rural Paraguay is puzzling, apparently leaving opportunities for arbitrage. Despite requiring additional labor and inputs, the price of cheese per liter of milk is lower than the price of a liter of fluid milk. We propose a framework of relational contracts to explain this puzzle. Consumers who desire a steady supply of milk enter into relational contracts with producers, paying a price premium for stable access to milk. This framework is consistent with our data. Producers sell to the same consumers year-round; producers with more variable milk production sell fewer months of the year and are more likely to sell cheese; and more price inelastic consumers are more loyal to their seller. Finally, we give evidence against other explanations for this pricing puzzle including the existence of more general non-dairy-specific market failures and the relative ease of transporting and storing cheese.

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1 Introduction

Long-term relationships and relational contracts are characterized by dynamic incentive compatibility constraints, or the requirement that both parties value the relationship enough that neither party wishes to renege (Macchiavello, 2022). Relational contracts may be especially important in developing countries where markets do not function well and for perishable goods which require individuals to trade with one another more frequently. These contracts often involve charging higher prices to loyal buyers who desire a more reliable supply. This is found for transactions involving fish (Weisbuch et al., 2000), cauliflower (Song and Ma, 2023), and ice (Ghani and Reed, 2022).

We find a puzzling relationship between the prices of locally-produced milk and cheese sold directly from the producer to the consumer in rural Paraguay. Fluid milk is sold at a relatively high price while cheese, which takes extra labor and materials to produce, is sold at a relatively low price. In 2007, a producer could convert 1,000 Gs worth of fluid milk into 632 Gs worth of cheese. Why wouldn't a cheese seller take advantage of an arbitrage opportunity, offer that fluid milk for sale at a slightly lower price, for example 900 Gs, and save herself the effort of converting it into cheese?

We argue that the high price of fluid milk is due to relational contracts. Many fluid milk consumers value having access to a stable supply of milk. On the other hand, milk producers must contend with a variable supply of milk. Consumers are willing to pay a higher price to get a reliable steady supply, and producers can process excess milk to produce cheese which they then sell at a relatively low price.

While relational contracts depend on the value of the relationship and the incentive to deviate, data does not usually measure the temptation to deviate. Macchiavello and Morjaria (2015) use variation in the Kenyan flower market caused by electoral violence and high Valentine's day demand to proxy for variation in temptation to deviate. Their insight is that one can measure the value of the relationship by seeing the difference between the prices that sellers get in the spot market and in relational contracts. If sellers can sell roses on the spot market for a higher price, but choose not to do so, this must mean the relationship is worth more to them than the price difference.

In this paper, we take a different strategy, directly asking both buyers and sellers if they could be tempted into reneging on their long-term relationships. While a disadvantage is that our measures are hypothetical, asking respondents if they would switch partners for a better price, it gives suggestive evidence of the value of the relationships. We see that 73% of consumers would not stop buying from their usual provider if another seller temporarily

offered them milk that was 200 Gs (approximately 17%) cheaper. Similarly, 70% of sellers would not stop selling to their usual customer if temporarily offered a price that was 200 Gs higher. Most milk transactions are conducted by the same partners year-round, with little switching to new partners.

We find suggestive evidence in accord with our relational contract hypothesis along two dimensions. First, with respect to variability of milk production, producers who sell milk but not cheese have less variable production. The more stable their production is, the more months of the year in which they sell milk. Second, using unique measures of consumers' price elasticity of demand and of their loyalty to their trading partner we find, as predicted, that price inelastic consumers are more likely to be loyal.

There are other potential explanations for the price discrepancy between milk and cheese. For example, market frictions in all rural Paraguayan markets (not just dairy markets) may be so severe as to make prices of all goods idiosyncratic. But, we compare the prices of fresh yuca and processed yuca starch and find that the prices of those two products are in accord with one another, which is evidence that at least some markets do function properly. Another alternative is that cheese may be less expensive than fluid milk because it can be stored for longer periods of time, but the data shows that Paraguayans do not store cheese for very long. And the possibility of storage wouldn't explain why a producer would sell cheese at a loss rather than offer their milk up at slightly lower price and take advantage of arbitrage opportunities. Another possibility we can counter is interlinked transactions. Loyalty is more common between partners who live within 300m of one another, but not between partners who have potentially interlinked transactions on multiple dimensions. We also provide suggestive evidence against explanations such as worries over unobservable milk quality among others. We believe that relational contracts ensuring stable milk transactions are the most likely explanation for the price differential we find.

The relational contracts we document in Paraguay, with loyal buyers and sellers who pay higher prices to ensure stability and reliability, have parallels with other markets in developing countries. Cajal-Grossi et al. (2023) show that Bangladeshi garment producers sell at a higher price to their relational buyers and a lower price to spot buyers. Song and Ma (2023) similarly find that relational contracts in Chinese wholesale vegetable markets involve higher prices with lower levels of variation in price and quantity. Ghani and Reed (2022) show that fishermen in relational contracts pay a higher price for ice in return for reliable supply. Macchiavello and Morjaria (2021) show that increased competition for coffee in Rwanda can cause relational contracts to break down due to the higher temptation to

break informal contracts when there is more competition.

Milk markets are especially important to study due to the nutritional function milk serves. Children in Ethiopia in households that own cows (even conditional on assets and income) consume more milk and are less likely to be stunted. This effect is significantly smaller in areas with better access to markets, and slightly smaller in villages with more cows, suggesting the importance of within-village milk trade and of understanding milk markets for their implications for child health (Hoddinott et al., 2015).

Incomplete milk markets may lead to inequality between milk producers with and without relational contracts. The integration of milk markets through the development of technologies for milk storage or maintenance of infrastructure to reduce transportation costs are promising. Also, extension programs to stabilize the milk production of small milk producers would allow them to more easily enter into relational contracts. These interventions would make it possible for all dairy farmers to participate in milk markets, and reduced milk prices would benefit consumers as well.

In Section 2, we describe the setting and the commodities. Section 3 gives the intuition behind the relational contract model and discusses testable hypotheses. Section 4 describes the data. Section 5 gives evidence that the relational contracts set-up can explain the puzzling pricing pattern, while Section 6 rules out alternative explanations. Finally, Section 7 concludes.

2 Background

Dairy markets occupy an important position in Paraguayan villages, where many people engage in the production, sale, and consumption of milk and cheese. Most milk-consuming households desire stable daily consumption of milk. However, milk supply is unstable and affected by uncontrollable factors (Manchester et al., 1994). Some of the instability is due to seasonal variation in the quality of pasture available to the animals, while some of the instability is idiosyncratic depending on how many calves were born how long ago. Bernard et al. (2018) document that even dairy processing companies have problems with irregular milk delivery by producers. They work with the company to offer producers free yogurt as a reward for regular milk delivery. Thus, the idea that dairy producers need to be offered a premium in return for regular milk supply is not new.

Dairy cooperatives play an important role in coordinating markets in many developed countries, though there is much variability in the presence of such institutions in developing

countries. Casaburi and Macchiavello (2019) focus on dairy markets in Kenya where farmers decide between selling to a cooperative or to itinerant traders, and informal sales appear to be rare. On the other hand, Blackmore et al. (2020) show that most milk in Kenya, Tanzania, and India, goes through the informal sector, and that the informal sector provides higher prices to producers. Similarly, only 8% of the Indian villages studied by Anagol et al. (2017) have a milk cooperative. Dairy cooperatives and formal milk sales are almost non-existent in the Paraguayan villages we study. Without these institutions, Paraguayan farmers and consumers have developed other mechanisms to cope with meeting milk demand despite unstable milk supply. Ferreira et al. (2007) study production constraints faced by dairy farmers in rural Paraguay. Over 70% of the milk produced by farmers in their study was sold within the neighborhood.

While people in Paraguayan villages actively engage in market transactions of milk and cheese, the prices appear to allow significant opportunities for arbitrage. It takes approximately 10 L of milk plus labor and rennet (the enzyme which turns milk into cheese) to make 1 kg of cheese. Paraguayan women are usually responsible for producing cheese, and imperfect labor markets may cause the shadow wage of women's labor to be close to zero. This might explain why fluid milk would be sold at the same price as the value of cheese it produces, but can not explain why fluid milk would be sold at a higher price than the value of cheese it produces. Yet this is precisely what we find. In 2007, the average milk price was 1,500 Gs/L while the cheese price was 9,000 Gs/kg.[1] This means that cheese makers converted 1,000 Gs worth of milk to make only 632 Gs worth of cheese.

Why is the price ratio of cheese to milk so low? One could imagine a cheese maker would like to sell milk instead of making and selling cheese. One could also imagine a middleman who takes advantage of this opportunity, buying milk from a cheese maker and selling it as fluid milk to consumers.[2] A cheese maker who makes one kilo of cheese from ten liters of milk and sells it at 9,000 Gs/kg will earn 900 Gs per liter. An arbitrager could offer to buy milk from this cheese maker at 1,000 Gs per liter and sell it to a consumer at a price lower than the market price, say, 1,050 Gs per liter. At first glance it seems surprising that nobody engages in this form of arbitrage.

It may be of interest to look at the dairy pricing system in the United States for comparison. This system similarly leads prices for drinking milk to be higher than prices for milk destined for manufacturing. Since the 1930s, a system of federal support prices and

[1] In 2007 the exchange rate was approximately 5,000 Gs per 1 USD.

[2] We do not look at overall profitability of owning cows, as do Anagol et al. (2017) and Attanasio and Augsburg (2018). We look at the profitability of selling milk versus cheese, conditional on producing milk.

federal milk marketing orders have developed which set minimum prices for milk.[3] Milk for drinking (fluid-grade milk) has a higher minimum price than milk for manufacturing products (manufacturing-grade milk). The main reasons for this price discrimination are (i) to prevent the fluid milk prices that consumers face from fluctuating due to a shortfall in milk production (Manchester et al., 1994) and (ii) to increase dairy farmer revenue by taking advantage of more inelastic demand for fluid milk compared to that for manufactured milk (Bailey, 2001; Cox and Chavas, 2001). Various public and private institutions, including the U.S. Department of Agriculture and (almost monopolistic) dairy cooperatives, must work together to maintain this price differential (Blayney and Manchester, 2001). It is interesting that the same price differential is informally maintained in rural Paraguayan dairy markets without these formal institutions.

3 Relational contracts and testable hypotheses

In this section, we provide an intuitive framework of relational contracts and explain how this framework can solve the Paraguayan dairy market pricing puzzle posed in the previous section. Here we provide just the intuition. A mathematical model can be found in Appendix A. Consumers contract with dairy producers to purchase a set quantity of milk at a set price, thus allowing consumers to enjoy a stable supply of milk at a stable price. Those contracts are not enforceable and either party can renege at any time.

Milk production is seasonal. Producers differ in how stable the quantity of milk they produce is across seasons. Consumers differ in how elastic their demand for milk is. Consumers with inelastic demand prefer to consume milk in every period, and are willing to pay a premium for a contract that allows them to do so.

There exist two markets for milk. Producers and consumers who have long-term relational contracts make transactions at predetermined contract prices in the contract market. Producers and consumers can agree to transact a certain amount of milk in every period at a given price. If the consumer purchases the contracted amount of milk from the contracted producer, then the contract continues into the next period. If either party does not maintain their side of the contract, the contract is terminated, the buyer and seller have no contract from the next period onward, and they conduct future interactions on the spot market. Given that both parties know each other well and often live near one another, social

[3]Before that, fluid milk distributors were willing to pay more for a stable supply of fluid milk with less seasonal variation while distributors paid less for milk used for manufactured products (Lininger, 1929).

sanctions may also be applied in case of breach of contract. We do not include this possibility in the mathematical model in Appendix A but decreased distance would make relational contracts easier to sustain.

Milk may also be sold in the spot market at a competitive price. There exists only one market for cheese, the spot market. Milk prices in the spot market are determined by demand and supply, so when supply is higher the price will be lower. In the high season the price of milk in the spot market faces a floor; it can not go below the equivalent milk price of cheese.

This model leads to some intuitive testable hypotheses. First and foremost, this model predicts the puzzle that was our starting point: the price of milk in relational contracts is higher than the equivalent milk-price of cheese. This also implies that producers will commonly be found to sell to the same consumers repeatedly year-round, while consumers will repeatedly purchase from the same producers year-round. Inasmuch as most consumers tend to be price inelastic, this will be true for most buyers and sellers. Consumers will be unwilling to leave their usual partner if offered a lower price for a few weeks, and producers will be unwilling to stop selling to their usual partner if offered a higher price for a few weeks.

The model also gives predictions about which producers will enter into relational contracts to sell milk, and which will sell cheese. First, producers who sell milk but not cheese are predicted to have less variable production compared to those who ever sell cheese. Relational contracts for milk sales involve the same amount of milk being sold in each time period. If the producer's milk production has low variability, he would prefer to sell it all as milk at a higher price. Second, as producers get a higher price for milk sold in a relational contract, any producer who sells cheese must do so because the amount he produces in his lowest production month is relatively low. Finally, the quantity of milk produced by producers who sell milk in more months is more stable. Producers with less stable production will not find relational contracts and will sell in fewer periods.

Finally, we can think about the purchasing behavior of consumers with different price elasticities of demand through the lens of the model. Consumers who are more price inelastic will be less willing to break their relational contract for a temporarily lower price. In other words, less elastic consumers are more likely to be loyal.

4 Data

We conducted agricultural household surveys with 449 households in 15 Paraguayan villages in 2007. For more details about the sample, see Ligon and Schechter (2012). The survey asked detailed retrospective information about production, sales, purchases, and gifts of milk and cheese at three points in time in the previous year: May 2006, September 2006, and January 2007. For every transaction we ask the quantity, price, identity of the trading partner, the relationship, the geographic distance between the two sides of the trade, and which actor (buyer or seller) traveled to make the transaction. We also have less detailed data on milk production from a smaller sample of 223 households from surveys conducted in 2002.

Summary statistics are shown in Table 1 and Appendix Table B-1.[4] In terms of seasonality, while 80 and 82% of milk producers produce a non-zero amount of milk in May and January, only 73% of them produce strictly positive amounts in September which is the end of winter in Paraguay. While more than half of the households produce milk in at least one month, only 11% of the households (or 19% of milk-producing households) engage in milk sales in at least one month. Conversely, 38% of households purchase milk in at least one period.

Given what we know about the identities of the two parties, we can characterize the relationship between the producer and consumer. The median distance between the consumer's house and the producer from whom he purchases is 300 meters. We see that 58% of consumers buy from a producer who lives no more than 300 meters away. This close distance has benefits both in terms of decreasing transportation costs and in terms of ease in sustaining a relational contract (for example due to increased possibilities for sanctioning close neighbors). We consider a consumer to have an interlinked relationship with the producer from which he purchases if they are linked in some other way in the social network.[5] This is true for 41% of milk buyers.

[4]We drop the four milk producers who produce more than 2000 liters per month. All four of those sellers reside in the same village which has many immigrants from Brazil (many of whom are of German descent), all of them speak Portuguese or German as their first language at home, and they sell to a larger milk-buying factory rather than to individual consumers living nearby. Results are similar if we do not drop these producers. None of these four producers purchase milk, so their omission does not affect the results focusing on milk purchases.

[5]The two are considered to have a link if the producer: is a close relative of the buyer, lent to or borrowed money from the buyer, is someone the buyer would go to if he needed money, is someone who would come to the buyer if he needed money, chose the buyer as a godfather, was chosen as a godfather by the buyer, gave to or received money from the buyer for health-related expenses, gave to or received agricultural gifts from the buyer, and lent land to or borrowed land from the buyer.

Table 1: Selected summary statistics

	Mean	SD	Count
Panel A: All households			
Milk producer	0.58	0.49	445
Monthly milk production (L)	210.30	245.73	258
Milk seller	0.11	0.32	445
Monthly milk sales (L)	198.25	337.38	50
Milk buyer	0.38	0.49	445
Monthly milk purchases (L)	19.37	17.79	168
Cheese producer	0.40	0.49	445
Monthly cheese production (kg)	15.17	20.18	179
Cheese seller	0.22	0.41	445
Monthly cheese sales (kg)	17.31	23.34	98
Cheese buyer	0.52	0.50	445
Monthly cheese purchases (kg)	2.35	2.10	232
Panel B: Milk buyers			
Loyal buyer	0.73	0.45	168
Extra milk (L) for 200Gs cheaper	9.04	13.66	168
No 1-5 year-old children in HH	0.55	0.50	168
Buyer within 300m	0.58	0.50	168
Interlinked transaction	0.41	0.49	168
# of risky choices made	1.63	1.64	136

Notes: Milk producers are households that produced milk in at least one of May 2006, September 2006, and January 2007. The same is true for milk sellers, milk buyers, cheese producers, cheese sellers, and cheese buyers. Monthly quantities average over all months for those who have positive quantities in at least one month, including any months with zero quantity.

In addition to measures of dairy production and transactions at three points in time in the past year, the survey was designed to measure other important variables. These include the loyalty of milk buyers, the price elasticity of demand of milk buyers, and the risk preference of all respondents.

To measure the loyalty of milk buyers, we asked: "If a new milk seller came to your house and offered to sell you milk temporarily, just for one week, at a price 200 Gs lower than what you usually pay, would you buy some milk from him?" If the respondent answered yes to this question, the enumerator followed up by asking: "What would you do during that week? i) continue to buy your usual amount of milk at the previous price from your usual seller, ii) buy a lower than usual amount of milk at the previous price from your usual seller, or iii) buy nothing from your usual seller." We consider a consumer to be loyal to his relational

contract either if he answers that he would not purchase from the temporary seller, or if he answers that he would purchase from the temporary seller while also continuing to buy the usual amount at the usual price from his usual seller. We see that 73% of milk buyers in our data are loyal. This measure is similar to that in Ghani and Reed (2022) who define loyal buyers as those who would wait to purchase from their usual retailer even if they had another way of getting the product (ice) earlier from a different retailer.

To measure the price elasticity of milk demand, we asked: "If the person from whom you usually buy milk lowered the price by 200 Gs per liter, how many extra liters of milk would you buy in a month?" This entails an approximately 17% decrease in price. More than half (54%) of respondents would not increase their milk purchases given this discount. Conditional on wanting to buy more milk, the average respondent claims they would like to purchase 20 extra liters in a month. Putting these two statistics together, the average milk buyer would buy 9 extra liters of milk per month if the price were lower. This can be compared to milk buyers' current average monthly purchases of 19 liters in all months (or 26 liters conditional on non-zero purchases). Unfortunately we did not ask the opposite question (how much less they would buy if the price were increased).

We asked all respondents hypothetical questions measuring their risk preferences. The first risk preference question asks the respondents to choose between a sure 50,000 Gs or a 50/50 chance between 40,000 and 100,000 Gs. The questions progress, decreasing the lower number from 40 to 30, to 20, to 10 thousand Gs until the respondent chose the sure thing.

In Section 6, we use some other variables when ruling out alternative explanations. These include incentivized experimental measures of altruism and trustworthiness, information on how long households store milk and cheese, and information about another integrated market (yuca and yuca starch).

5 Empirical results

In this section, we first show evidence of the milk and cheese pricing puzzle in rural Paraguayan villages. The existence of relational contracts implies that the price of milk is higher than the equivalent milk price of cheese as we find in the data. Then, we show that the other empirical implications of the relational contract model are supported by data. On the producer side, we predict that the more stable a producer's milk production is, the more likely he is to engage in a relational contract. On the consumer side, we predict that more inelastic consumers are more likely to engage in relational contracts. In section 6, we rule out other

possible explanations for the disproportionately low price of cheese.

The milk and cheese being sold in rural Paraguay are locally produced and traded, they do not come from manufacturing plants or stores. When one of the co-authors of this paper lived in a rural Paraguayan village in the 1990s, she noticed that cheese was surprisingly inexpensive given how much work it was for the producers to make. One could buy a kilo of cheese for less than the price of the milk it took to make it (ignoring the fact that cheese production also involves rennet and the producer's time).

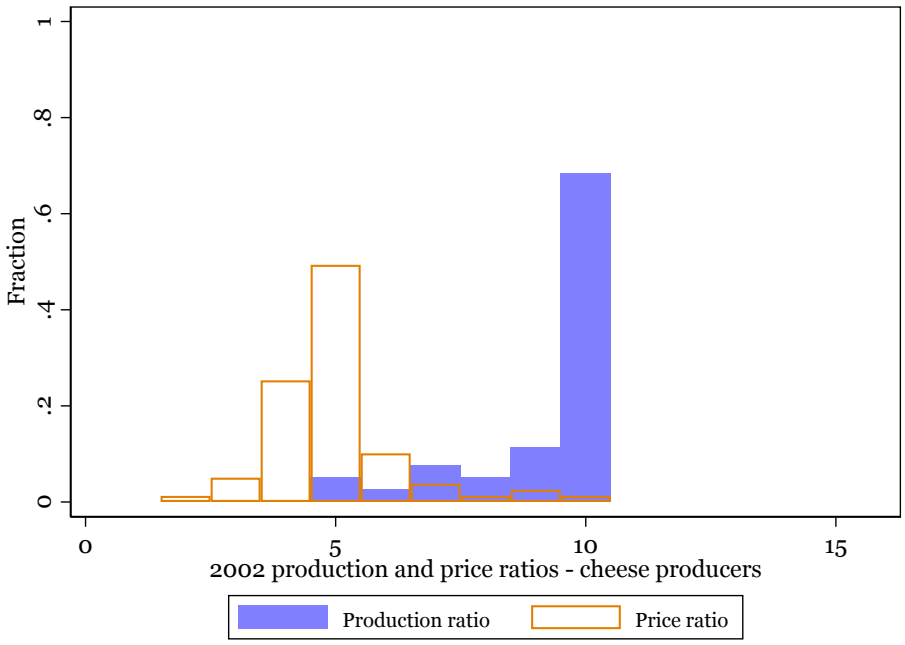
In a data collection exercise in 2002 surveying farmers in rural villages across the country, it became obvious that this pricing puzzle was a more general phenomenon. Becoming more interested in exploring this puzzle, a 2007 survey in the same villages dedicated a section of the questionnaire to milk and cheese. Figure 1 shows histograms of the production and price ratios in 2002 and 2007. In 2002 we only have price data from producers, while in 2007 we have price data from both producers and consumers. We see that in 2002 it takes on average 9.1 liters of milk (plus rennet and labor) to make a kilo cheese, while a kilo of cheese only costs, on average, 5 times the price of a liter of milk. On average, cheese producers convert 1000 Gs worth of milk to 567 Gs worth of cheese. The results in 2007 are quite similar with an average production ratio of 10 liters of milk to make a kilo of cheese, the average price of cheese being 6.2 times the price of milk, and cheese producers converting 1000 Gs worth of milk to 632 Gs worth of cheese. Figure 1b does not show any noticeable difference in price ratios for milk sellers compared to milk buyers.[6]

The relational contracts model could explain this price differential between milk sold as milk and milk used for cheese. Section 3 lays out three additional families of testable implications. First are the more obvious trappings of relational contracts. Consumers should tend to purchase from the same producer year-round, and producers should tend to sell to the same consumers year-round. Consumers and producers should not be willing to leave their usual partner for a temporarily better price. Second are a series of predictions about how the variability of a producer's milk production will affect their sales choices. Finally, consumers with more inelastic milk demand should be more loyal to the partner with whom they have a contract. In this section, we show that these additional implications of the relational contracts model are supported by the data.

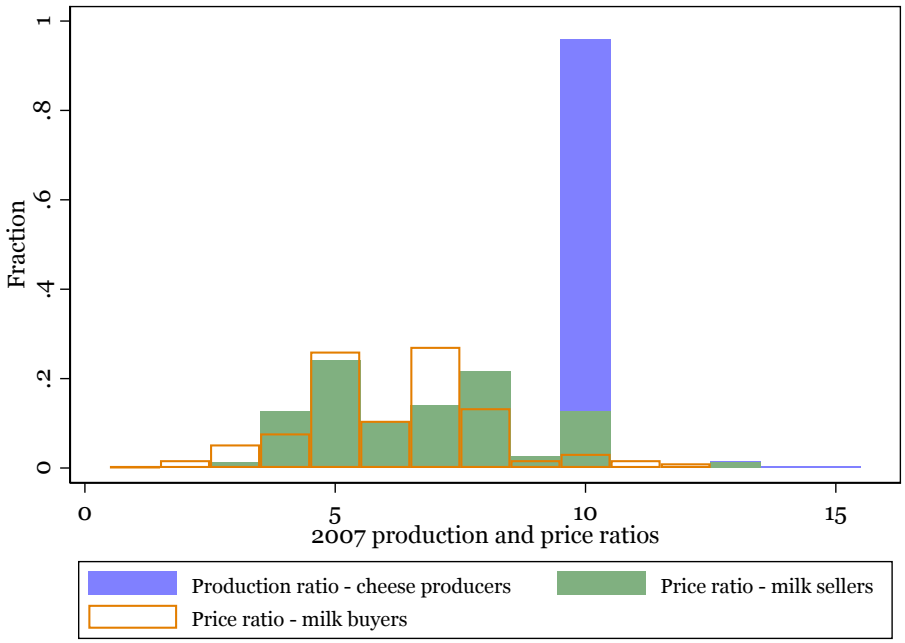
[6]The price ratio in 2002 shows a large mass at 5, because the modal price of cheese was 5,000 and the modal price of milk was 1,000. Due to inflation, by 2007 the cheese price had a main mode at 10,000 with a secondary mode at 8,000 and the milk price had a main mode at 1,500 with secondary modes at 1,000 and 2,000.

Figure 1: Production and price ratios for milk and cheese

(a)



(b)



Notes: Panel a shows how many liters of milk it took to make a kilo of cheese (the production ratio) and how much a kilo of cheese cost compared to a liter of milk (the price ratio) in 2002 for all cheese producers. Panel b shows the production ratio for cheese producers, and separates out the price ratio for milk sellers and milk buyers in 2007.

5.1 Empirical characteristics of relational contracts

We start by giving direct evidence that milk markets are characterized by relational contracts. Figure 2 shows that all producers who sold milk in all three months (May, September, and January) sold to the same consumer in all three of those months. Most producers who sold milk in two months sold to the same person in both months. The same patterns hold for those who purchase milk. Trading partners are very stable over time. In conversations prior to the surveying, it became clear that both milk buyers and milk sellers had informal contracts with their partners that they were loathe to break even for a better price, and hypothetical questions in the survey confirm this.

5.2 Dairy sales patterns depend on variability of production

There are a series of predictions about how production variability will affect a producer's decision to sell milk and cheese. Table 2 shows the size and variability of milk production by seller types. There are 258 milk producers (defined as households that produced some milk in any of the three months), and they are classified into the following four mutually exclusive categories: (i) those who never sold milk or cheese in any of the months (Non-seller), (ii) those who sold milk in at least one month but never sold cheese (Milk seller), (iii) those who sold both milk and cheese in at least one month (Milk and cheese seller),[7] and (iv) those who sold cheese in at least one month but never sold milk (Cheese seller).

First, we compare those who sell only milk with those who sell cheese in at least one period (regardless of whether they do or do not also sell milk). We predicted that producers who sell milk but not cheese have less variable production compared to those who ever sell cheese. Milk sales quantities are relatively constant over time in the relational contract. Only variable production can make it worth spending the time and effort to make cheese to then sell at a relatively lower price. This is supported by the data. For example, mean milk production is only 35% higher ((385-285)/285) than minimum milk production (production in the month with the lowest production) for those who sell only milk. In contrast, the mean is 80% higher than the minimum for those who sell both milk and cheese, and 62% higher for those who only sell cheese. The coefficient of variation (CV, or the standard deviation divided by the mean) of milk production for those who sell only milk shown in column (2) is significantly lower than the CV for those who ever sell cheese in columns (3) and (4) with

[7] They can sell milk and cheese in different months: for example, they might sell milk only in May and cheese only in September.

Figure 2: Repeated milk transactions

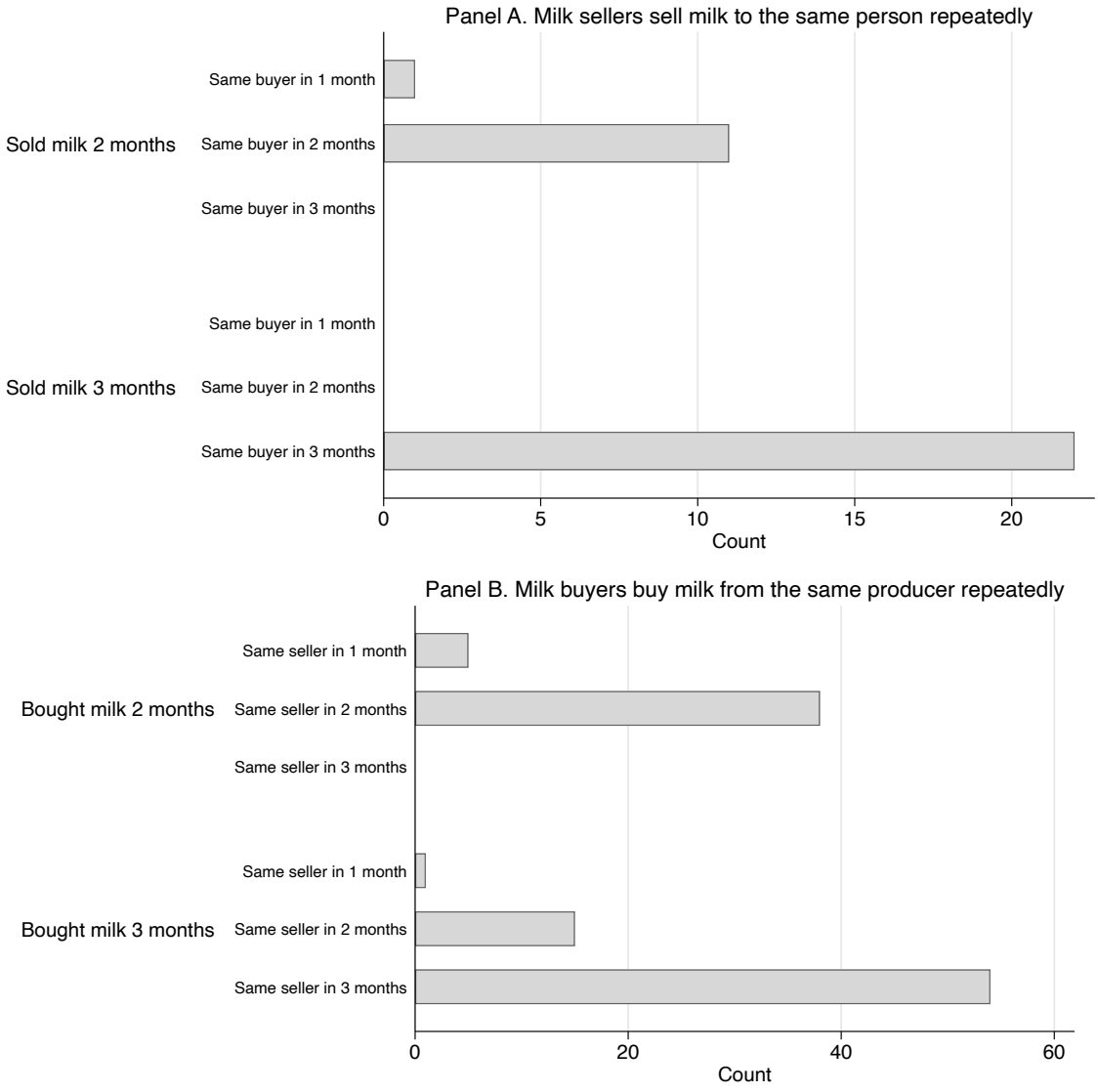


Table 2: Milk production and sales decisions

	(1) Non-seller mean/sd	(2) Milk seller mean/sd	(3) Milk and cheese seller mean/sd	(4) Cheese seller mean/sd
Mean milk prod.	96.75	384.60	343.17	307.04
	(64.03)	(410.24)	(330.82)	(244.04)
SD milk prod.	62.65	111.04	183.88	125.29
	(49.91)	(102.49)	(129.30)	(101.32)
CV milk prod.	0.90	0.42	0.75	0.56
	(0.64)	(0.38)	(0.56)	(0.44)
Minimum milk prod.	43.05	284.48	191.43	189.53
	(68.00)	(370.44)	(278.45)	(224.51)
Number of months with any milk prod.	2.08	2.79	2.43	2.65
	(0.81)	(0.49)	(0.81)	(0.60)
Number of cattle owned	8.06	15.24	14.43	17.20
	(11.40)	(19.41)	(17.53)	(22.10)
Number of cows owned	3.26	6.07	6.57	7.32
	(5.15)	(9.55)	(8.40)	(10.99)
Observations	133	29	21	75

Notes: Observations in column (1) produce but never sell dairy products, in column (2) only ever sell milk, in column (3) sell both milk and cheese, and in column (4) only ever sell cheese. Mean monthly milk production is averaged over the three months; minimum monthly milk production is production in the month they produce the least. Both include months in which no milk was produced. Cattle includes bulls, oxen, cows, heifers, and calves.

a p-value of 0.059.[8]

Third, milk production of producers who sell milk in more months is predicted to be more stable than the production of those who sell in fewer months. Producers with less stable production will not find relational contracts. This is borne out by the results in Table 3. In column (1), we regress the number of months in which a milk producer sells milk on the CV of their milk production. The CV of milk production is quite negatively correlated with the number of months selling milk. This effect might mechanically be due to the fact that producers who do not produce milk in a specific month can thus not sell any milk in that month. So, in column (2) we add an additional control for the number of months in which the producer produces milk. The number of months producing milk is not a significant predictor of the number of months selling milk. As the relational contract model suggests, the variability in milk production is the important determinant of selling milk. In column (2), a one standard deviation (0.42) increase in the CV of milk production among the producers in the regression, leads to a 0.56 decrease in the number of months selling milk. Columns (3) and (4) instead use an indicator for selling milk in all three survey months as the outcome variable. As predicted, more stable milk producers are more likely to always sell milk.

[8]Comparing milk sellers to milk and cheese sellers in column (3) the p-value is 0.016, and comparing the milk sellers to those who only sell cheese in column (4) the p-value is 0.133.

Table 3: Relationship between milk production CV and # months milk sold

	# months selling milk		Sold milk in all months	
	(1)	(2)	(3)	(4)
CV of milk production	-1.480***	-1.346**	-1.013***	-0.904**
	(0.336)	(0.548)	(0.225)	(0.377)
# months producing milk		0.117		0.0944
		(0.425)		(0.272)
Observations	42	42	42	42
Outcome mean	2.26	2.26	0.52	0.52
Controls	Yes	Yes	Yes	Yes
Village FE	Yes	Yes	Yes	Yes

Notes: Sample includes households that sold milk in at least one survey month and produced milk in at least two survey months. Additional control variables include log of wealth, age and schooling years of the household head, maximum schooling years of the household members, and the household size. Heteroskedasticity-robust standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

5.3 Loyalty, elasticity, and variability of purchases

The model suggests that more price inelastic consumers will be more loyal. It also suggests that relational contracts are more likely between neighbors who may be better able to impose sanctions on one another for reneging. We have measures of loyalty, elasticity, and distance. As discussed in Section 4, we asked customers whether they would decrease milk purchases from their current supplier if a new supplier offered to bring them milk at a price that was 200 Gs per liter lower than what they usually pay, just for one week. Loyal customers are those who claim they would continue to buy the usual amount at the usual price from the usual seller. Our measure of elasticity is the number of extra liters a consumer claims they would buy in a month if the person from whom they usually purchase milk were to lower the price by 200 Gs per liter.

The regression equation to investigate the relationship between buyer loyalty and proxies for price elasticity of demand is:

$$L_{iv} = E_{iv}\gamma + X'_{iv}\beta + \nu_v + \epsilon_{iv}. \tag{1}$$

The variable L_{iv} is an indicator for consumer i in village v being loyal, E_{iv} are proxies for the elasticity of milk demand, and X_{iv} is a vector of other control variables. Controls include log of wealth, the age of the household head, the years of schooling of the household head,

the maximum years of schooling of any household member, and family size. Finally, ν_v is a village fixed effect and ϵ_{iv} is an error term.

Table 4: Relationship between loyalty and elasticity

	(1) Loyal buyer	(2) Loyal buyer	(3) Loyal buyer	(4) Loyal buyer	(5) Loyal buyer	(6) Loyal buyer	(7) Loyal buyer
Elasticity	-0.00754***					-0.00738***	-0.00657***
	(0.00241)					(0.00264)	(0.00246)
No 1-5 year-old children		-0.163*				-0.132	-0.0991
		(0.0902)				(0.104)	(0.0855)
Buyer within 300m			0.177**			0.163*	0.162**
			(0.0747)			(0.0833)	(0.0727)
Interlinked transaction				0.0978		0.0314	0.0335
				(0.0717)		(0.0883)	(0.0710)
# of risky choices made					-0.0142	-0.0129	
					(0.0241)	(0.0235)	
Observations	168	168	168	168	136	136	168
Outcome mean	0.73	0.73	0.73	0.73	0.70	0.70	0.73
RHS variable mean	9.04	0.55	0.58	0.41	1.63		
Controls	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Village FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes

Notes: Sample includes households who bought milk in at least one month. Loyal is a binary indicator for their continuing to purchase from their usual seller even with a temporary offer of a better price elsewhere. Elasticity is the number of extra liters they would buy if the price decreased by 200 Gs. Not all households responded to the risk aversion questions, hence the lower sample size in columns with that control. Additional control variables include: log of wealth, age and years of schooling of household head, maximum years of schooling of household members, and household size. Heteroskedasticity-robust standard errors in parentheses: * $p < 0.10$, ** $p < 0.05$, *** $p < 0.01$.

Our main proxy for price elasticity is the number of extra liters the consumer would purchase at the lower price. We also explore other variables which we expect might be proxies for elasticity. This includes an indicator for not having any children between 1 and 5 years old, who are more likely to drink cow's milk on a daily basis. It also includes the number of risky choices made in the hypothetical risk game, since we expect those who make more risky choices to place less value on stability and be less loyal. We also explore the geographic distance between the buyer and seller as a measure of their ease in imposing sanctions on one another. In section 6.4.2, we discuss the coefficient on the interlinked transaction variable and reject the alternative explanation of these patterns as being due to interlinked transactions.

Table 4 shows the results. Column (1) shows that more price inelastic consumers are also more loyal. A one standard deviation (13.66) liter increase in the consumer's elasticity, as measured by the number of extra liters they would want to buy at a lower price, is associated with a 10 percentage point decrease in loyalty. The coefficient on the indicator for the household not having a child aged 1-5 suggests that households without children in that age range are less loyal, potentially because those with young children place greater

value on having a stable milk supply for child nutrition. Consumers who purchase from a producer living no more than 300 meters away are more loyal in accord with findings in Ghani and Reed (2022), potentially because enforcement is easier at shorter distances. There is no significant correlation between risk aversion and loyalty.

6 Alternative Explanations

Section 5 presented evidence consistent with our hypotheses that the milk and cheese pricing puzzle is explained by relational contracts designed to avoid instability in milk consumption by inelastic consumers. While that framework is consistent with the data, other mechanisms might also explain the pricing puzzle. For example, perhaps markets in rural Paraguayan villages do not function more generally, and arbitrage opportunities exist for other integrated products. Or, perhaps cheese has a lower price because it is cheaper to transport and easier to store for extended periods of time compared with milk. Or, perhaps there are relational contracts for milk, but the rationale for these contracts is concern over milk quality rather than concern over stability in the quantity of milk. Other possibilities include altruistic cheese sellers, interlinked transactions, entry barriers to the fluid milk market, and the existence of other valuable by-products from cheese production. In this subsection, we discuss each of these possibilities in turn with an attempt to rule them out.

6.1 Malfunctioning markets

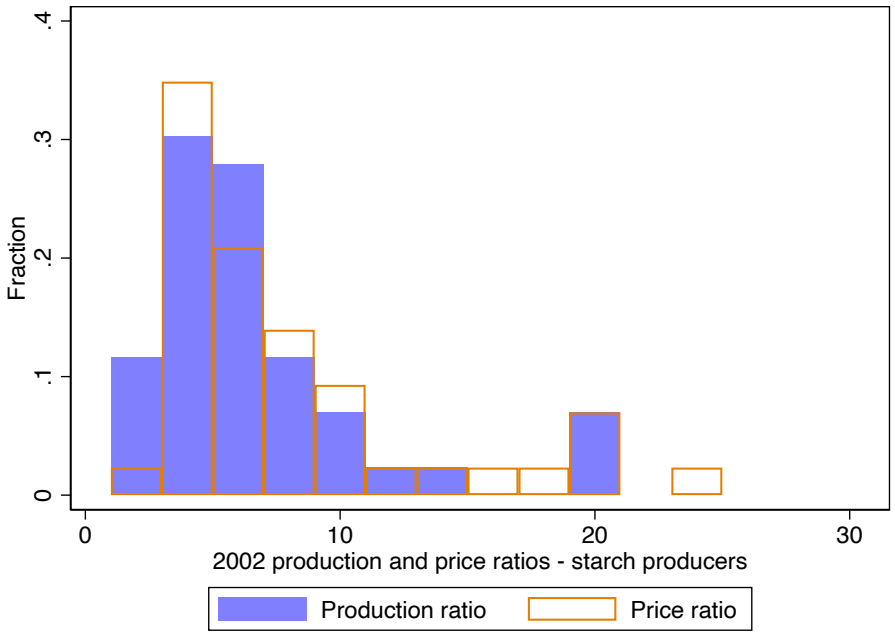
One possibility to explain the relatively low price of cheese could be that market mechanisms do not work in Paraguayan villages more generally. Information frictions, travel costs, and labor market imperfections may be so extreme as to render the law of one price irrelevant. To show that this is not true, we look at another pair of integrated products: yuca and yuca starch. Yuca (also known as cassava or manioc) is a commonly grown root crop in Paraguayan villages. It is the staple crop, no meal is complete without yuca, and 91% of households in our data grow it. Yuca starch (also known as tapioca) is starch extracted from the yuca root.

Figure 3 shows histograms of the production and price ratios of yuca and yuca starch in 2002 and 2007. According to the 2002 survey, 6.6 kilos of yuca yield approximately one kilo of tapioca starch. In that period, the price of a kilo of tapioca starch was 7.9 times higher than the price of a kilo of yuca.[9] The respective numbers in 2007 are a production ratio of 7.6

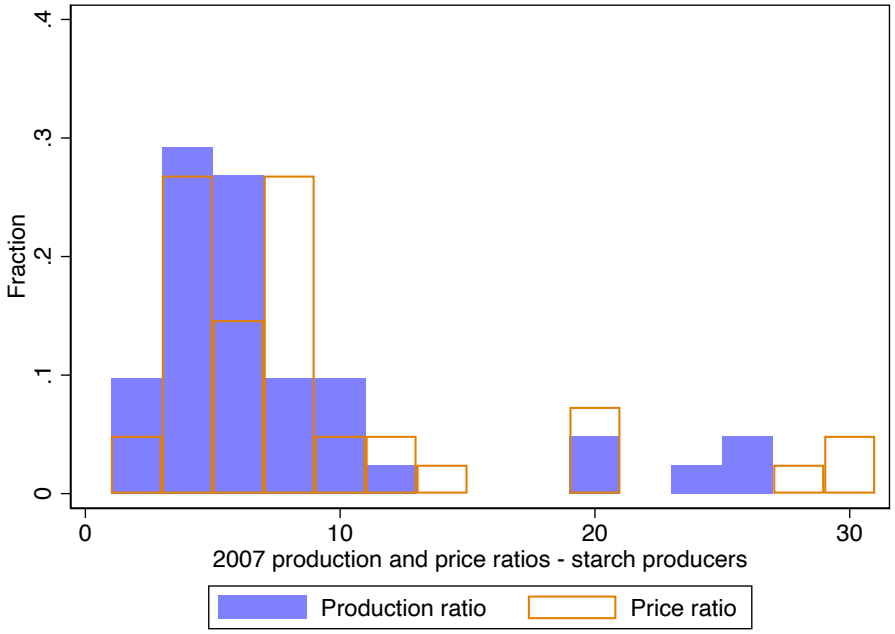
[9]These numbers exclude a few outliers in a village in which many households sells yuca at a significantly

Figure 3: Production and price ratios for yuca and starch

(a)



(b)



Notes: Panel a shows how many kilos of yuca it takes to make a kilo of starch (the production ratio) and how much a kilo of starch costs compared to a kilo of yuca (the price ratio) in 2002 for all households that produced starch. Panel b shows the same ratios for 2007. These figures exclude outliers with ratios over 30, see Appendix Figure B-1 for the histogram with data from the full sample.

and price ratio of 8.9. On average, starch producers convert 1,000 Gs worth of yuca to 1,840 Gs worth of starch in 2002 (or 1,752 Gs worth in 2007). Considering the significant labor costs needed to make a kilogram of yuca starch, the costs of labor appear to be reasonably incorporated.[10] This gives evidence that prices in Paraguayan villages do equalize for other integrated goods. There must be something special about milk and cheese.

6.2 Easier storage and lower transportation costs of cheese

One obvious difference between milk and cheese is the fact that cheese is easier to transport and can be stored for longer periods of time. Milk is liquid and bulky, implying that the transportation cost of milk is higher than that of cheese. If the transportation costs are borne by milk sellers, then the fluid milk price should be higher than marginal cost of production even without relational contracts. In our 2007 survey, we asked milk buyers and sellers which party was responsible for transporting the milk. It is almost always the buyer, not the seller, who pays the transportation cost. We see 89% of milk buyers and 76% of milk sellers report that the buyer goes to the seller's residence to pick up the milk they purchase. Because the transportation cost is typically borne by the milk buyer, not the seller, transportation costs can not explain the relatively high price of milk.

Milk is also quite perishable, while cheese has a longer shelf-life. This could cause milk to have a relatively higher price. Cheese can be a way for a farmer to avoid selling milk at a low price or wasting it if he doesn't have any sales opportunities and can not preserve the milk safely for longer periods of time. Still, there should be an arbitrage criterion such that storage will occur until the price differential is eliminated (Hennessy and Roosen, 2003). The fact that the price differential is not eliminated suggests that storage can not be the explanation for the pricing puzzle.

In addition, because this cheese is generally sold to local consumers, and because villagers have issues with refrigeration which make it difficult to store for long periods of time, we do not believe that cheese can be stored from the high period to the low period. We asked respondents the longest period of time they had kept milk and cheese before using or selling it in the past year. Cheese does keep longer than milk, with 99% of households consuming or selling milk within a week, and 48% of households consuming or selling cheese within a

lower price to a large factory. If we were to include those observations, the price of a kilo of tapioca starch would be 14.9 times higher than the price of a kilo of yuca. The histograms including the outliers can be found in Appendix Figure B-1.

[10]The process of making tapioca starch involves peeling, grating, and washing - all of which are usually done manually.

week. That said, we do not find evidence that Paraguayans store cheese across seasons. The median of the longest number of days a household stores dairy products are 1 for milk and 8 for cheese. Even the 75th percentile figures are only 2 and 8 days, respectively. While this confirms that cheese is easier to store than milk, the possibility of storing cheese for one week rather than one day is unlikely to explain the price ratio between milk and cheese.

6.3 Relational contract for milk quality

Milk can be watered-down by milk producers, which results in low-quality milk. Relational contracts may be in place, but may be meant to insure milk quality rather than quantity. Since milk quality is not recorded in our data-set, it is difficult to disprove this possibility directly. However, we consider this possibility as unlikely for three reasons.

First, milk is sold raw and is boiled by the purchaser. According to rural Paraguayans, watered-down milk can often be distinguished from pure milk because it boils and bubbles differently. Buyers who found themselves deceived would spread the word and would not purchase again from the unscrupulous seller. Thus, milk sellers have an incentive to provide unadulterated milk, decreasing the need for relational contracts for good quality milk. Rustagi and Kroell (2022) present evidence that consumers in India are overly confident about their ability to detect adulterated milk and overly optimistic about the quality of milk they purchase. Still, in the presence of over-confidence there is no need to contract on milk quality.

Second, if reputation as a good-quality milk provider were necessary to sell milk, we might expect that more trustworthy milk producers would be more likely to become milk sellers. Thus, we investigate the relationship between being a milk seller and trustworthiness. Trustworthiness is measured by the share returned as a trustee in an incentivized trust game played in 2002 (for more detail, see Schechter (2007)). Since not all households in the 2007 survey played the trust game in 2002, the sample size is smaller (110 milk producers). To test this, we run the following regression:

$$M_{iv} = T_{iv}\alpha + X'_{iv}\beta + \nu_v + \epsilon_{iv}$$

where M_{iv} is a dummy variable for being a milk seller, and T_{iv} is the measure of trustworthiness. The results are shown in columns (1) and (3) of Table 5. The coefficient on trustworthiness is not statistically significantly different from zero. This suggests that being trustworthy is not an important determinant of whether a milk producer becomes a milk

seller.

Table 5: Selling dairy products and social preferences

	Sold milk		Sold cheese	
	(1)	(2)	(3)	(4)
Trustworthiness	-0.127		0.117	
	(0.220)		(0.250)	
Altruism		0.00459		-0.0203
		(0.0118)		(0.0151)
Observations	110	210	110	210
Outcome mean	0.37	0.39	0.37	0.39
Controls	Yes	Yes	Yes	Yes
Village FE	Yes	Yes	Yes	Yes

Notes: The sample is all milk producers. A milk producer is a milk (cheese) seller if he sells milk (cheese) in at least one of May 2006, September 2006, or January 2007. Dependent variables are an indicator for being a milk seller in columns (1) and (2), and an indicator for being a cheese seller in columns (3) and (4). Trustworthiness is the share returned as a trustee in a trust game in 2002. Altruism is the amount transferred out of 14 thousand Gs in a dictator game in 2007. Additional control variables include: log of wealth, age and years of schooling of household head, maximum years of schooling of household members, and household size. Heteroskedasticity-robust standard errors in parentheses: * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

Finally, recall that 73% of buyers would not stop buying from their usual provider if *temporarily* (for one week) offered a 200 Gs lower price by another seller. We compare this with the lower share of 44% of buyers who said they would not stop buying from their usual provider if *permanently* offered a 200 Gs lower price if they had to travel one kilometer to get the milk. This second question unfortunately mixes travel costs with willingness to switch from one permanent provider to another. Still, the fact that so many more customers are willing to leave their usual provider for a permanently better deal (even with increased travel costs), but are not willing to do so for a temporarily better deal suggests that stable quantities of milk are more important to consumers than the identity of the partner and their trust in that partner's quality.

6.4 Other potentially plausible explanations

6.4.1 Altruistic cheese sellers

Prices for cheese might be low if altruistic milk producers make cheese and sell it to poor households at a lower price. Cheese could be seen as an effective transfer from the rich to the poor. However, it would be unusual for altruism to be shown only in cheese markets,

not in other markets. And, it would be much less work for an altruistic dairy producer to sell milk at lower prices rather than spending the extra effort to turn it into cheese. If this explanation were true, we would expect cheese sellers to be more altruistic than other milk producers. To investigate this possibility, we measure altruism as the amount transferred out of 14 thousand Gs in an incentivized dictator game (for details, see Ligon and Schechter (2012)) played by 210 milk producers. The results are shown in columns (2) and (4) of Table 5. We find no correlation between altruism and selling cheese and conclude that it is unlikely that altruistic behaviors explain the pricing puzzle.

6.4.2 Interlinked transactions

Given that dairy transactions often take place between individuals who live close geographically, it may be the case that dairy transactions are interlinked with other financial transactions (Bardhan, 1980). As a result of selling cheese at a low price, cheese sellers may benefit in other ways such as being able to borrow money or receive gifts. We test whether consumers who have interlinked transactions with the producer are more likely to be loyal in column (4) of Table 4. There is a positive but insignificant correlation between having an interlinked transaction and being a loyal buyer. In columns (6) and (7), we additionally concurrently control for geographic distance between the buyer and seller. The coefficient on geographic distance barely changes, while the coefficient on having an interlinked transaction gets smaller. This suggests that the relatively low price of liquid milk is not due to benefits provided by other interlinked transactions.

6.4.3 Entry barriers to selling milk

Barriers to entry to sell in fluid milk markets would increase the market power of fluid milk sellers, allowing them to raise milk prices without relational contracts. Such barriers for milk producers seem unlikely, since it would imply barriers that are higher for milk compared to cheese producers. Producers do not require a large initial investment to sell fluid milk, at most they need some empty bottles and barriers to entry should be low.

6.4.4 By-products from cheese production

In the process of making cheese, milk is separated into curds and whey. While only the curds are further processed to make cheese, whey is also nutritious and is used in cooking and to feed pigs. If whey were an important by-product of cheese production, the high value of

whey could compensate for the lower price of cheese. Although Paraguayans do make use of whey, it is not a highly valued product. Our survey asked about by-products of animal production and not a single respondent ever mentioned whey. Whey is not a commodity that is ever sold. Therefore, we do not believe that whey can explain the price puzzle.

7 Conclusion

Individuals living in rural areas commonly purchase locally-produced consumption goods directly from the producer. In the case of rural Paraguayan dairy markets, a liter of fluid milk costs 58% more than the same amount of milk would cost after being converted to cheese. Given that converting milk to cheese is labor-intensive, this price differential is puzzling.

We propose relational contracts as an explanation for this differential. Individual producers have milk production levels which vary across the year, while consumers with inelastic demand prefer to purchase the same amount year round. In order to ensure access to a stable supply of milk, they pay a price premium. Using new empirical survey-based measures of elasticity and loyalty, we find that consumers with price inelastic demand for fluid milk are more loyal to their usual trading partner. We give evidence against other explanations such as more general market imperfections and the relative ease of storing cheese compared to milk.

This study shows the informal institutions which arise in the absence of an affordable centralized modern milk market. Rural households transact with one another in relational contracts. Fear of unstable supply and prices discourage them from taking advantage of short-run arbitrage opportunities and reneging on their long-term relationships.

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A Model of relational contracts

Assume milk consumers and producers play a multi-period infinitely repeated game. There are two seasons: a high production season and a low production season. Each is realized with 50% probability. Denote milk production in the high season as $y_h = y + \nu$ and in the low season as $y_l = y - \nu$, where a positive constant ν is a deviation from the mean production, y. Production costs are the same in the two seasons. Let $\delta < 1$ be the common discount factor of both consumers and producers.

On the consumer side, we denote the consumer's Hicksian demand for milk by a linear willingness-to-pay function: $p(y) = (\beta_0 - y)\beta_1$, where p is the price the consumer is willing to pay for y units of milk; $\beta_1 > 0$ is the slope of the demand curve and is proportional to the consumer's demand elasticity for milk, and $\beta_0\beta_1 > 0$ is the lowest price at which a consumer would demand no fluid milk (the choke price). Consumers with more elastic demand have smaller β_1 (meaning they are more responsive to price). Consumers choose between establishing a relational contract with a producer and buying milk in the spot market. We assume that reneging on the relational contract results in the termination of the relationship and the producer and consumer will trade on the spot market forever after. Finally, consumers pay an additional per-period cost, κ, for transactions on the spot market, which captures the cost of searching for new sellers and negotiating prices and quantities.[11]

A.1 Spot market prices

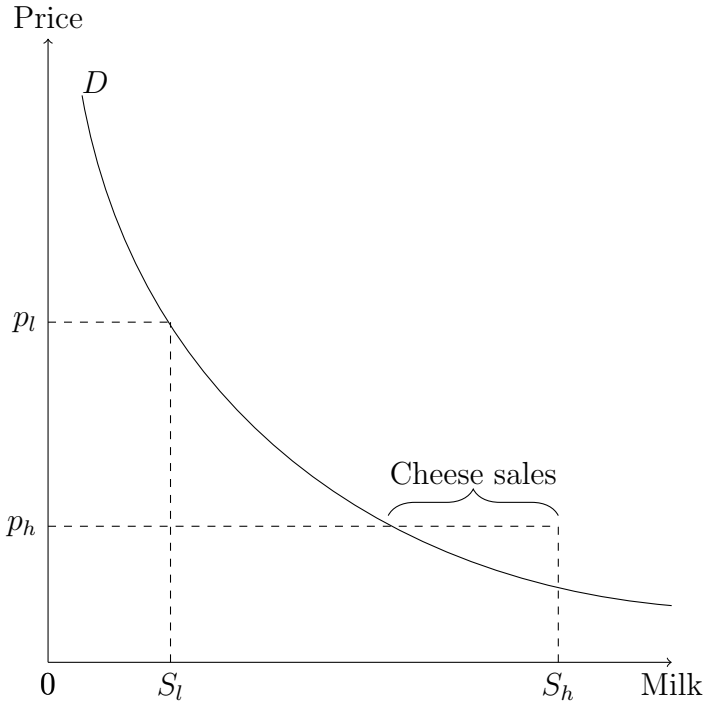
We assume that spot market milk prices are determined by aggregate demand and supply and that each consumer and producer does not account for his decision's effects on those aggregates. In other words, we consider a partial equilibrium model. Aggregate demand in the spot market is the sum of milk demanded by all consumers who do not have relational contracts. Aggregate supply is the sum of milk produced minus the amount of milk sold through relational contracts. Denote aggregate demand as D and low- and high-season aggregate supply as S_l and S_h respectively. Milk producers also have the option to use their milk production to produce cheese and can sell that on the spot market for an exogenously given price. They may choose this option when the spot-market milk price is too low.

Milk prices are determined as shown in Figure A-1. In the low season, the price of milk, p_l, is determined by milk demand and supply. In the high season, the price of milk p_h has a

[11] This type of cost on the buyers' side on the spot market has been assumed in, for instance, Macchiavello and Morjaria (2015) as transport and intermediation costs and Song and Ma (2023) as rationing on the spot market.

floor anchored by the cheese price since producers can choose to sell cheese if the milk price is too low. Here, p_h is determined by the milk to cheese conversion rate and the market price of cheese. We assume that the choke price of consumers is higher than the low-season price: $\beta_0\beta_1 > p_l$. This implies that demand will still be positive when the price is high in the low season.

Figure A-1: Aggregate demand and supply of milk



A.2 Relational contracts

Given the price of milk on the spot market, we consider when consumers and producers prefer to establish relational contracts. We call the contracted price of milk $\bar{p}$.[12]

On the consumer side, the consumer surplus per period from the relational contract is

$$S_R = \frac{1}{2}(\beta_0\beta_1 - \bar{p})\left(\beta_0 - \frac{\bar{p}}{\beta_1}\right) = \frac{(\beta_0\beta_1 - \bar{p})^2}{2\beta_1}.$$

[12]This does not mean that the contracted price of milk is exogenously given. The price can be determined through negotiation. See below for more discussion.

The consumer's expected per-period consumer surplus on the spot market is

$$S_S = \frac{1}{2}\left\{\frac{(\beta_0\beta_1 - p_l)^2}{2\beta_1} + \frac{(\beta_0\beta_1 - p_h)^2}{2\beta_1}\right\} = \frac{(\beta_0\beta_1 - p_l)^2 + (\beta_0\beta_1 - p_h)^2}{4\beta_1}.$$

In a relational contract, a consumer prefers to keep his contract rather than renege this period and purchase in the spot market from the next period onward. For the incentive compatibility constraint, it is sufficient to consider consumer deviations in the high season since the milk price in the spot market is lower then. This constraint is formalized as

$$\frac{1}{1-\delta}S_R > \frac{(\beta_0\beta_1 - p_h)^2}{2\beta_1} + \frac{\delta}{1-\delta}S_S - \frac{1}{1-\delta}\kappa,$$

where the last term captures the additional cost buyers have to pay for transactions in the spot market.

The price $\bar{p}$ satisfying this condition is

$$\bar{p} < \beta_0\beta_1 - \sqrt{\left(1-\frac{\delta}{2}\right)(\beta_0\beta_1 - p_h)^2 + \frac{\delta}{2}(\beta_0\beta_1 - p_l)^2 - 2\beta_1\kappa}, \quad \text{or}$$
$$\bar{p} > \beta_0\beta_1 + \sqrt{\left(1-\frac{\delta}{2}\right)(\beta_0\beta_1 - p_h)^2 + \frac{\delta}{2}(\beta_0\beta_1 - p_l)^2 - 2\beta_1\kappa}.$$

However, the latter would imply that the price in the relational contract is higher than the choke price, hence no consumer would establish the contract. Therefore, the condition for the relational contract price $\bar{p}$ so that the consumer prefers to establish and stay in a relational contract is

$$\bar{p} < \beta_0\beta_1 - \sqrt{\left(1-\frac{\delta}{2}\right)(\beta_0\beta_1 - p_h)^2 + \frac{\delta}{2}(\beta_0\beta_1 - p_l)^2 - 2\beta_1\kappa}.$$

On the producer side, first we assume that only farmers who can deliver the promised amount of milk to their customers even in the low season can have contracts. Specifically, we assume that only farmers with $y - \nu - \bar{y} > 0$ can have contracts, where $\bar{y}$ is the amount of milk promised to be sold to the customer. If a consumer knows that he will not be able to buy the promised amount of milk from a producer in the low season, the consumer would not want to have a contract with that farmer in the first place. Also, for simplicity, we assume that a farmer can have a contract with at most one consumer.

The producer's expected profit from having a relational contract per period is

$$\pi_R = \frac{1}{2}\left(p_l(y-\nu-\bar{y}) + p_h(y+\nu-\bar{y})\right) + \bar{p}\bar{y}$$

and the producer's per-period expected profit without a contract is

$$\pi_S = \frac{1}{2}\left(p_l(y-\nu) + p_h(y+\nu)\right).$$

We assume production costs do not vary across the two methods for selling milk and so ignore them. The producer will choose to keep a relational contract rather than renege if the present-value of the profit from keeping the promise is larger than the payoff from selling in the spot market this period and in the future. Suppose that the deviation in the low season when the spot market price is high is more profitable than that in the high season: $p_l(y-\nu) > p_h(y+\nu)$. Then, it is sufficient to consider the following incentive compatibility condition with respect to deviating in the low season:

$$\frac{1}{1-\delta}\pi_R > p_l(y-\nu) + \frac{\delta}{1-\delta}\pi_S.$$

The case where the high-season deviation is more profitable provides the same testable hypotheses.

The above condition can be transformed in the following way:

$$\begin{aligned}
&\frac{1}{1-\delta}\pi_R > p_l(y-\nu) + \frac{\delta}{1-\delta}\pi_S \\
\Leftrightarrow\ &\frac{1}{2}\left(p_l(y-\nu-\bar{y}) + p_h(y+\nu-\bar{y})\right) + \bar{p}\bar{y} > (1-\delta)p_l(y-\nu) + \frac{\delta}{2}\left(p_l(y-\nu) + p_h(y+\nu)\right) \\
\Leftrightarrow\ &p_l(y-\nu-\bar{y}) + p_h(y+\nu-\bar{y}) + 2\bar{p}\bar{y} > 2(1-\delta)p_l(y-\nu) + \delta\left(p_l(y-\nu) + p_h(y+\nu)\right) \\
\Leftrightarrow\ &-p_l\bar{y} + p_h(y+\nu-\bar{y}) + 2\bar{p}\bar{y} > (1-\delta)p_l(y-\nu) + \delta p_h(y+\nu) \\
\Leftrightarrow\ &\left(2\bar{p} - (p_l+p_h)\right)\bar{y} > (1-\delta)\left(p_l(y-\nu) - p_h(y+\nu)\right) \\
\Leftrightarrow\ &\left(2\bar{p} - (p_l+p_h)\right)\left(\beta_0 - \frac{\bar{p}}{\beta_1}\right) > (1-\delta)\left(p_l(y-\nu) - p_h(y+\nu)\right) \\
\Leftrightarrow\ &\left(2\bar{p} - (p_l+p_h)\right)\left(\bar{p} - \beta_0\beta_1\right) < -\beta_1(1-\delta)\left(p_l(y-\nu) - p_h(y+\nu)\right) \\
\Leftrightarrow\ &2\bar{p}^2 - (p_l+p_h+2\beta_0\beta_1)\bar{p} + (p_l+p_h)\beta_0\beta_1 + \beta_1(1-\delta)\left(p_l(y-\nu) - p_h(y+\nu)\right) < 0.
\end{aligned}$$

Hence, this condition is satisfied when

$$\frac{(p_l + p_h + 2\beta_0\beta_1) - \sqrt{(2\beta_0\beta_1 - (p_l + p_h))^2 - 8\beta_1(1-\delta)\left(p_l(y-\nu) - p_h(y+\nu)\right)}}{4} < \bar{p}$$
$$< \frac{(p_l + p_h + 2\beta_0\beta_1) + \sqrt{(2\beta_0\beta_1 - (p_l + p_h))^2 - 8\beta_1(1-\delta)\left(p_l(y-\nu) - p_h(y+\nu)\right)}}{4}$$

Let

$$A \equiv \beta_0\beta_1 - \sqrt{\left(1 - \frac{\delta}{2}\right)(\beta_0\beta_1 - p_h)^2 + \frac{\delta}{2}(\beta_0\beta_1 - p_l)^2 - 2\beta_1\kappa},$$
$$B \equiv \frac{(p_l + p_h + 2\beta_0\beta_1) - \sqrt{(2\beta_0\beta_1 - (p_l + p_h))^2 - 8\beta_1(1-\delta)\left(p_l(y-\nu) - p_h(y+\nu)\right)}}{4}, \quad \text{and}$$
$$C \equiv \frac{(p_l + p_h + 2\beta_0\beta_1) + \sqrt{(2\beta_0\beta_1 - (p_l + p_h))^2 - 8\beta_1(1-\delta)\left(p_l(y-\nu) - p_h(y+\nu)\right)}}{4}.$$

Combining the consumer and producer sides, a consumer and producer are willing to establish a relational contract if there exists a contract price $\bar{p}$ such that

$$B < \bar{p} < \min\{A, C\}.$$

Since $p_l(y-\nu) > p_h(y+\nu)$,

$$B > \frac{p_l + p_h + 2\beta_0\beta_1 - (2\beta_0\beta_1 - (p_l + p_h))}{4} = \frac{p_l + p_h}{2} > \frac{p_h + p_h}{2} = p_h,$$

where the first inequality used $\beta_0\beta_1 > p_l > \frac{p_l + p_h}{2}$, that is, the choke price is higher than the average spot market price. Remember that p_h is the milk price in the high season, which is assumed to be the equivalent milk price of cheese since producers can sell redundant milk as cheese. Hence, we obtain the following hypothesis:

H1. The relational contract price for milk is higher than the equivalent milk price of cheese.

To make the model tractable and derive meaningful model predictions, here we consider

the comparative statics when the discount factor is close to 1.[13] Note that

$$C - A \to_{\delta \to 1} \frac{(p_l + p_h + 2\beta_0\beta_1) + (2\beta_0\beta_1 - (p_l + p_h))}{4} - \beta_0\beta_1 + \sqrt{\frac{1}{2}\left((\beta_0\beta_1 - p_h)^2 + (\beta_0\beta_1 - p_l)^2\right) - 2\beta_1\kappa}$$
$$= \sqrt{\frac{1}{2}\left((\beta_0\beta_1 - p_h)^2 + (\beta_0\beta_1 - p_l)^2\right) - 2\beta_1\kappa} > 0.$$

Therefore, $C > A$, and the condition that a relational contract price must satisfy in order to sustain a contract is

$$\frac{p_l + p_h}{2} < \bar{p} < \beta_0\beta_1 - \sqrt{\frac{1}{2}\left((\beta_0\beta_1 - p_h)^2 + (\beta_0\beta_1 - p_l)^2\right) - 2\beta_1\kappa}.$$

There exists $\bar{p}$ satisfying this condition if and only if

$$\beta_1 > \frac{(p_l - p_h)^2}{8\kappa}.$$

This means that more elastic consumers (that is, consumers with smaller β_1) are less likely to establish a relational contract since there does not exist a contract price satisfying the condition for such customers. This provides the following hypothesis:

H2. Less elastic consumers are more likely to have relational contracts.

Note that, for the relational contract to hold, the price can be anywhere in the given range. Buyers and sellers can negotiate over the contract price such that the condition is satisfied.

By assumption, farmers who cannot deliver the promised amount of milk to their customers in the low season will have to sell in the spot market. This implies that producers with more variable production, or higher ν, will not enter into relational contracts. This leads to the following hypothesis:

H3. Producers with more variable production are less likely to have relational contracts.

[13] This is reasonable in our study context as villagers can have transactions repeatedly for a long period of time.

B Appendix Tables and Figures

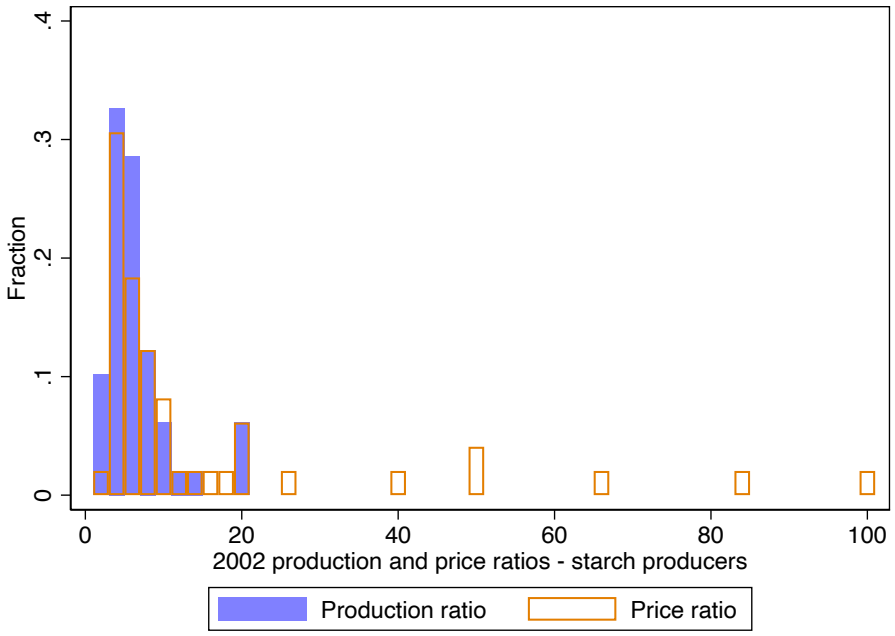
Table B-1: Summary statistics (household control variables)

	Mean	SD	Count
Log of wealth (1,000 Gs)	10.18	1.90	445
Schooling years of household head	4.74	2.92	445
Age of household head	53.49	14.88	445
Maximum schooling years of the household members	8.30	3.73	445
Household size	4.92	2.39	445
Trustworthiness	0.42	0.20	158
Altruism	8.94	2.66	369
# of risky choices made	1.57	1.62	361

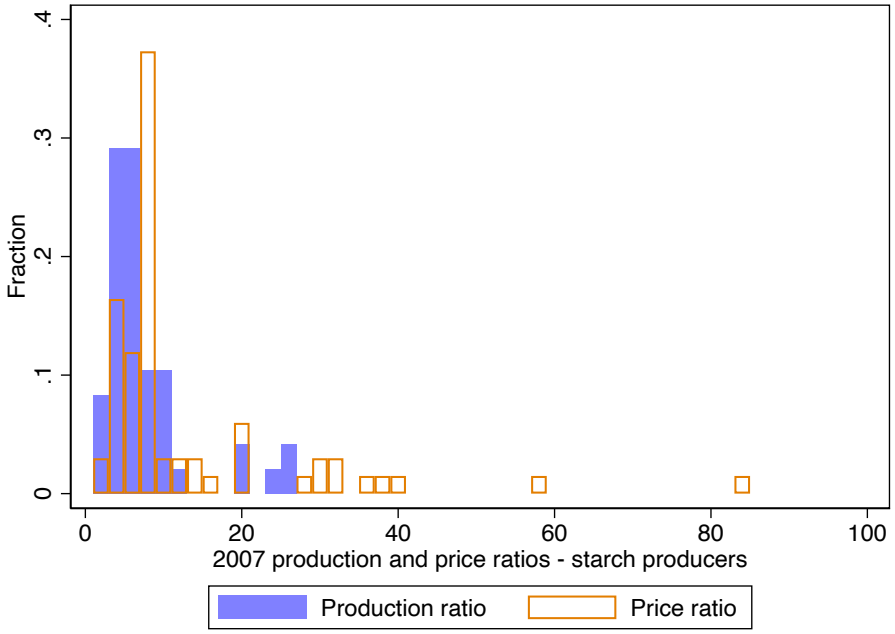
Notes: Trustworthiness is the share returned as a trustee in a trust game in 2002. Altruism is the amount transferred out of 14 thousand Gs in a dictator game in 2007.

Figure B-1: Production and price ratios for yuca and starch

(a)



(b)



Notes: The top figure shows how many kilos of yuca it takes to make a kilo of starch (the production ratio) and how much a kilo of starch costs compared to a kilo of yuca (the price ratio) in 2002 for all households that produced starch. The bottom panel shows the same ratios for 2007. These figures include outliers with ratios over 30.