Interlinked Transactions and Pass-Through: Experimental Evidence from Sierra Leone*

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Abstract

Interlinked transactions in which output prices are determined jointly with the terms of a credit contract are an important feature of many business relationships, particularly in developing economies. We present results from a randomized experiment designed to study how value is passed along the agricultural supply chain in the presence of such interlinkages. In response to an increase in a trader's wholesale price, we find limited pass-through of the price to farmers. However we also find a large increase in the likelihood that traders provide credit to farmers, suggesting that the value of the wholesale price increase was passed to farmers along a different margin. We develop a model of interlinked transactions that shows how price and credit pass-through are determined, and verify its predictions empirically. Our work suggests that the presence of interlinkages is a candidate explanation for low rates of price pass-through that have been observed, but one with substantially different implications for welfare than others.

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1 Introduction

Rural areas of developing economies often lack formal financial institutions. In their absence, agents in the rural supply chain have emerged as a substitute source of credit for producers and households. For instance, an intermediary buying agricultural produce for a wholesaler may provide payment in advance to the farmer for output, allowing the farmer to smooth consumption. A long tradition in development economics has observed that relationships such as these lead to transactions that are *interlinked*: the price at which output is purchased is determined jointly with the terms of the credit contract, and vice versa (e.g. Bardhan, 1980, Braverman and Stiglitz, 1982, Bell, 1988, Grosh, 1994, Deb and Suri, 2012). More generally, firm-to-firm credit is more prominent for small firms and when financial institutions are weak (e.g. Petersen and Rajan, 1997; Fisman and Love, 2003).[1]

As a consequence, product market conditions may affect the supply of credit. If the wholesale value of a farmer's produce for the intermediary rises, so might the credit supplied to the farmer. In this paper, we argue that the presence of such interlinkages affects how value is passed through the supply chain from buyers to producers. Interlinkages may provide an important explanation, particularly in remote areas of developing economies, for why a low rate of price pass-through has been observed, both in aggregated market prices (Atkin and Donaldson, 2013) and in the transactions of individual traders (Fafchamps and Hill, 2008; Mitra et al., 2013). These findings have been interpreted as evidence of price rigidity, imperfect competition, or large distribution costs, all of which have the implication that in the presence of low price pass-through, incentives for producers are distorted (for a review see Burstein and Gopinath, 2012). Our work suggests interlinkages are additional mechanism that may generate low price pass-through, but with a different implication for producers and the efficiency of the supply chain. If buyers pass through some of a good's value in credit that is later repaid in lower prices, there may be in fact more transmission of incentives than is observed if one only looks at transaction prices, and producer welfare may be higher. This observation enhances our understanding of how producer investment decisions may respond to policies that affect border prices, such as trade liberalization and export subsidies.

Our paper makes three contributions. First, we discuss the results of a randomized experiment in a set of agricultural markets designed to elucidate the separate margins through which value is passed through by individual traders. The experiment is set in the cocoa industry of Sierra Leone, West Africa, where interlinked transactions such as the one described above are

[1] In the United States, small businesses rely on trade credit for about 60% of their external finance (Mach and Wolken, 2006).

common. Survey evidence suggests that interlinkages are common across Africa. For instance, a report on East and Southern Africa by IFAD (2003, pg. ii) observes "credit under contract farming arrangements is one of the major (indeed, often, the only) forms of access to production finance among smallholders."[2] We pay a treatment group of intermediaries (i.e. farmgate traders) a per-unit bonus for delivering cocoa (above a certain quality standard) to wholesalers. Using detailed data on the prices and credit supplied to farmers, we show that although average pass-through of the bonus is small in terms of prices, it is substantial in terms of credit outlay. The experiment confirms the two conjectures above: product market conditions faced by the intermediary affect substantially the supply of credit to farmers, and the pass-through of the cocoa's value is masked when one only observes the price at which the cocoa is transacted. To the best of our knowledge, this is the first experiment targeting the propagation of incentives across agents along agricultural value chains.

Second, we develop a simple theoretical model that helps to interpret the results. In our model, changes in the price paid to intermediaries for output shift the share of producers engaged in interlinked transactions as opposed to simply selling on a spot market. In the interlinked transaction, intermediaries pay the producer in advance for the good, a form of forward credit that the producers use to smooth consumption.[3] This credit is paid back in the form of a lower output price. Therefore, the average rate of price pass-through is determined by the measure of producers who endogenously switch into (or out of) interlinked transactions. In response to an increase in the price they receive from wholesalers, intermediaries may choose to give credit to more producers. For certain parameter values, as these producers move from the spot market to the interlinked transaction, the observed price they receive falls. While farmers benefit from credit provision, this switching between contracts drives down the average rate of price pass-through further than the rate that would obtain if the intermediary were simply an oligopsonist on the spot market. This insight speaks to a recent literature that uses the price pass-through rate as a tool to infer the shares of surplus captured by producers, consumers, and intermediaries in the economy (Fabinger and Weyl, 2013; Atkin and Donaldson, 2013). In the presence of interlinked credit and output markets, a complete welfare analysis needs to include "credit pass-through" as well as the standard price pass-through.

[2]Contract farming here is construed broadly, to cover contractual relations between small-scale traders and farmers, as in our setting, as well as relations between farmers and large-scale firms with outgrowing schemes. An overview of these issues is provided by Bijman (2008). Case study evidence from Ghana, India, Madagascar, Mozambique and Nicaragua is given by Barrett et. al. (2012).

[3]Intermediaries have also been observed to write contracts that transfer risk from farmers to traders, providing insurance against adverse price and productivity shocks that may affect the farmer. While we acknowledge this is another important margin on which intermediaries may pass through value to farmers, it is not common in our setting, and we leave it to be studied in others.

Third, we verify empirically some of the predictions of the model, namely that price and credit pass-through are substitutes. Using correlations in the baseline data, we show that, consistent with the model, credit provision to farmers is higher in markets where proxies for the return to credit are higher. We also show that higher credit provision is negatively correlated with farm-gate prices. Then, using an analysis of heterogeneous treatments effects in the experiment, we show that those markets that experience a stronger credit response to our bonus show a lower rate of price pass-through. The magnitudes are substantial economically. A village in which the bonus raised the likelihood of credit provision to farmers by the estimated average treatment effect displays price pass-through lower by one-sixth to one-third of perfect pass-through, relative to a village with no effect of the bonus on credit.

As emphasized by Bauer (1954) and Fafchamps (2004), the presence of many layers of intermediation is a defining characteristic of agricultural markets in sub-Saharan Africa. Besides simply transporting goods, intermediaries also provide services such as information, insurance, and, as in our context, credit. While the literature has acknowledged this role, there is little quantitative evidence about how traders' own incentives affect the level of service provision. This paper shows they do, and that the magnitude of this effect can be substantial.

One important difference between ours and other related studies is that while pass-through is generally considered as the response of a price to a change in the world price received by all traders in a the market, our experiment studies pass-through when prices are raised only for some. We provide our model as a simple framework to show how these effects may be relevant for pass-through in the case of a price shock affecting all traders. We then show that the substitutability between credit and prices finds support in the baseline data (i.e. collected before the experiment). In addition, we show that our empirical results are similar when several traders are treated in a given market.

Our work supports a view of intermediaries as service providers, as opposed to a view in which they are simply arbitrageurs.[4] In this sense our work is related to that of Rubenstein and Wolinsky (1987) and Antrás and Costinot (2012), who develop models in which traders provide a service to the market by alleviating search frictions. It is also related to the work on micro-finance by Maitra, Mitra, Mookherjee, Motta, and Visaria (2012) who identify another way in which traders may add value. The authors argue that, given the strength of traders'

[4]Given the context, our work also contributes to the extensive literature on agricultural traders in Africa in particular, initiated by Bauer (1954) and Hill (1963) and continued by Fafchamps (2004), Fafchamps, Gabre-Madhin and Minten (2005), Osborne (2005), Fafchamps and Hill (2008) and Casaburi, Glennerster and Suri (2012), among others. More broadly, we also add to the literature studying the nature of inter-firm relationships in developing economies (McMillan and Woodruff, 1999; Banerjee and Duflo, 2000; Macchiavello and Morjaria 2012; Blouin and Macchiavello, 2013).

relationships with clients, traders may have more information about default risk and be able to recommend higher quality clients to financial institutions.

The paper proceeds as follows. In section 2 we describe our experiment and provide summary statistics on traders and the markets used in the study. Section 3 discusses our experimental results. In section 4 we present a model of pass-through in interlinked transactions and assess its welfare implications. Section 5 tests further predictions of the model. Section 6 concludes.

2 An Experiment in the Sierra Leone Cocoa Industry

In order to elucidate the multiple margins through which intermediaries may pass value to producers in response to a change in their price incentives, we run an experiment in a set of agricultural markets within the cocoa industry of Sierra Leone, West Africa, a setting in which interlinked transactions including credit are common.

2.1 The Sierra Leone Cocoa Value Chain

West Africa produces two-thirds of the world cocoa supply. Though given its small size Sierra Leone accounts for only a small share of this total, cocoa is important nationally. The crop comprised 8.6% of exports in 2009, and is by far the country's largest export crop by value, according to the UN COMTRADE database. The industry has also grown tremendously in the last decade, with the value of exports growing ten-fold between 2009 and 2001, when the country's decade long civil war came to an end.

The within-country cocoa trade in Sierra Leone is highly fragmented across many traders, and the supply chain has many links, similar to other agricultural markets in developing economies (for examples in Africa see Fafchamps, Gabre-Madhin, and Minten, 2005, and Osborne, 2005).[5] Farmers sell to traders, who sell to wholesalers in small towns, who in turn sell to exporters in larger towns, who in turn sell to buyers at the port. While the study of pass-through is surely relevant at each of these links in the supply chain, we focus on the final link closest to production, and leave the examination of other levels for future research. Working at this level is not only the most feasible from a cost-effectiveness perspective, but it also allows us to examine

[5] Sierra Leone's cocoa industry is similar to those in Cameroon, Côte d'Ivoire and Nigeria all of which liberalized during the 1990s and became similarly fragmented (Gilbert, 2009). Though Sierra Leone does have an official marketing board, the organization has been defunct since the war, and the government is responsible for a negligible share of purchases. A potential explanation for the lack of vertical integration in the market in the absence of a strong marketing board are the stringent legal restrictions on the transaction of land discussed in Acemoglu, Reed and Robinson (2013). These, along with weak legal institutions more broadly, would make vertical integration of the supply chain difficult, if not impossible.

heterogeneity in pass-through across many different markets. As one moves further down the supply chain, the number of markets for cocoa necessarily falls quite quickly.

As the summary statistics presented below will show, the provision of loans by traders to farmers is a defining characteristic of this industry, making the context similar to those in other developing economies discussed in the papers cited in the introduction. Traders will offer farmers credit before and during the harvesting season, which typically lasts from the beginning of the rainy season in July until early January of the following year. Traders then allow farmers to repay the loan in cocoa by selling at a below market price for subsequent sales until the loan has been repaid. This credit could be productive, and allow the farmer to invest in post-harvesting quality-enhancing processing (i.e. fermenting and drying the cocoa beans), or could be simply a payment advance that the farmer uses for consumption.

Traders also use credit provision as compensation for the guarantee that the farmer will sell to them at harvest, "locking in" supply, preventing other traders that visit the market to compete for that farmer's cocoa. This creates a co-existence of "spot markets" (i.e. traders competing for cocoa from a given farmer after the harvest occurs) and interlinked transactions. A necessary condition for credit to generate this lock-in effect is that it must be costly for a farmer to strategically default on the loan. This is the case in our context for at least two reasons. First, customary authorities play an important role in enforcing contracts even if access to modern courts is very limited (e.g. Acemoglu, Reed, and Robinson, 2013, Sandefur and Siddiqi, 2013). Second, as in standard relational contracting models, traders may threaten not to offer credit in the subsequent season in the event of a default (Fafchamps, 2004, 2006, Macchiavello and Morjaria, 2013).

2.2 Experimental Design

We developed our experiment in partnership with five privately owned wholesalers in Sierra Leone's cocoa producing Eastern Province, three in the town of Segbwema, and one each in the towns Pendembu and Kailahun.[6] These wholesalers collect cocoa in their warehouses, and then sell it on to exporters in the provincial capital of Kenema. Our sample includes 80 traders, henceforth study traders. This comprises almost the complete set of traders who do business

[6]These towns are now quite remote, accessible only by unpaved roads that can become impassible in the rainy season. During the colonial period, however, Pendembu was a prosperous trading town and the final stop on the Sierra Leone Railroad, which was dismantled and sold by the government of Siaka Stevens in the 1974. The decline in the country's cocoa industry since then can be observed at the massive abandoned produce warehouse where the end of the tracks once lay. Exporters we visited in 2011 joked with some cynicism that the cocoa stocks of the largest wholesalers in Pendembu could not come close to filling it.

regularly with these wholesalers.[7]

We paid a bonus of 150 Leones—5.6% of the average wholesale price—for high quality cocoa to randomly selected traders, who themselves buy directly from farmers. The bonus in our experiment was designed to model fluctuations in the market price received by traders, who themselves sell to wholesalers. Our experiment runs from September to December of 2011, roughly the end of the harvest season. At the beginning of the experiment, traders were informed the treatment would last till about the end of the harvest season.

The bonus generates cross-sectional variation in prices received by traders during this time period. While prices do also vary over time because of international market fluctuations, these changes are not an attractive source of variation for our purposes. Such changes are infrequent, making it difficult to use them to estimate a pass-through rate unconfounded by other seasonal variables such as rainfall that may affect supply throughout the season. In addition, time series of prices and in particular credit provision the would be required for a study based on world price fluctuations are typically not available across many producer and trader relationships. For these reasons, we chose an experimental approach in our study.

We then measure how this bonus affects prices and credit delivered to farmers across the different villages in which the traders operate. By estimating heterogeneous treatment effects across villages and comparing them, we are able to study the relation between these two margins, using our model to guide the analysis.

2.3 Data and Random Assignment

2.3.1 Trader Data

Randomization occurred at the trader level. To improve the statistical power of our experiment, we implement a pairwise randomization strategy, first grouping traders in pairs and then allocating one trader to treatment in each of the pairs (Bruhn and McKenzie, 2009). We first match traders within wholesalers according to a self-reported estimate of the number of grade A bags that they had sold since the beginning of the cocoa season, a plausible proxy for the scale of their business. We felt this a useful proxy for similarity in capacity for price and credit pass-through, since the ability to give credit will be a function of the total wealth of the trader, which, given constant or increasing margins, should rise with the scale of business. Having

[7] In a census of regular business partners of the wholesalers, we counted originally 84 traders. Two were outliers with respect to baseline quantity, and could not be matched to other traders in our randomization strategy. One other trader was lost due to attrition–he did not return after the census and no follow up data on either credit or prices could be collected. Since all of the analysis is done within matched pairs, his pair is also dropped from the analysis. Given the pairwise randomization, this attrition is not a threat to the internal validity of our study.

matched the traders, we assigned treatment and control within pairs using a random number generator.

Over the course of the experiment we collect a variety of data from traders. Summary statistics are presented in Table 1. At baseline, we interviewed each trader about their experience in the industry, and collected basic demographic indicators. These results are presented in Panel A of Table 1. Traders operate at a small scale in terms of value. At average cocoa prices and 2011 exchange rates, the self-estimate of bags sold per trader since the beginning of the season is approximately $4,360.[8] Traders are experienced, with an average of 6.5 years selling to the wholesaler. Their average age is 38 years, 82% of the 46 year male life expectancy reported by World Health Organization in 2011. Traders are well off relative to the population. 58% have a cement or tile floor as opposed to dirt or thatch, a useful indicator of asset wealth in this context, and 92% own a mobile phone. The 2007 National Public Services survey of reports 18% and 8% respectively for ownership of these two assets among all households in rural areas. 83% of traders have access to a storage facility.[9] The third column of Table 1 shows that treatment and control are balanced on all trader-level covariates.

During the experiment, when traders arrived at the warehouse, inspectors from our research team measured and documented the quality of their shipment. We collected these data for about two weeks before treatment assignments were announced. Panel B of Table 1 shows deliveries from this period. Given the short length of pre-treatment period data collection, we miss baseline data for some traders and markets (details reported in the table notes). These results confirm that treatment and control traders are balanced on the volume of their business: treatment traders sold on average 2,478 pounds and control traders sold 2,594. Treatment traders did sell a lower amount of grade A cocoa, but the difference is not statistically significant (T = -1.005).

In these shipment data, we collected the price per pound paid to farmers, and the name of the village in which the cocoa was purchased. As emphasized by Atkin and Donaldson (2013), it is important to measure prices only for narrowly defined homogenous goods, as one must not conflate pass-through and changes in the composition of quality. The quality of cocoa is indeed heterogeneous, and market prices depend on a variety of characteristics including moisture content, mold, germination, lack of fermentation and a discoloration known as slate. Though there is no official measure of quality in the market, wholesalers and traders agree on broad

[8] This is calculated as the control group's average number of bags, 30.3, times the approximate pounds per bag, 180 times the average dollar price of cocoa over this period, Le. 3,200, divided by 4,000, the nominal exchange rate.

[9] Field work suggests that traders for the most part do not perform long-term storage or other post-harvest processing activities.

determinants of quality that are consistent with international standards (see CABISCO, 2002). A quality premium exists in the market to some extent. In order to measure pass-through for given classes of quality, we worked with the partner wholesalers to refine a quality grading that correlates well with baseline prices. When traders arrive at the warehouse, inspectors hired by the research team sampled 50 beans from each bag, and used them to create an index of quality—grades A, B or C—which was then applied to each bag. In Appendix A we discuss in greater detail the construction of the grades, and their relationship to wholesale prices and international standards of cocoa quality.

Traders typically mix cocoa from different farmers of the same village in the same bag, and so farmer prices reported are the average per unit purchase price paid by a trader in a village at the time a bag was purchased. Farmer prices reported in baseline in Panel B show that traders in treatment and control were balanced on the prices they paid to farmers, and confirm that average prices of grade A cocoa are larger than for grades B and C: in the control group the average price paid for grade A is Le. 3,120 and the average price paid for B or C is Le. 3,050.

Finally, in the baseline we asked traders to list each farmer they buy from regularly and all of the villages in which they buy. For each farmer, we asked whether the trader had given the farmer a loan over the past 12 months. These results are shown in Panel C. The average trader operates in 4.6 villages, and buys from 25.9 farmers, on average 5.7 per village. In the baseline survey traders have given at least one loan to on average 70% of their clients. In order to study the impact of trader treatment on credit provision, in November and December we asked again the traders if they had given loans in the previous month to the farmers listed at baseline, in the final round asking the amount of the last loan.

One caveat to our empirical analysis is that, due to budget constraints, all the data are self-reported by traders when they visit the wholesaler warehouses. In Section 5, we argue that our results cannot be explained by strategic misreporting.

2.3.2 Village Data

In the baseline, we confirmed the existence of 125 villages in which study traders had reported purchasing cocoa over the previous year. For our analysis, we focus on the eighty villages for which we have at least one observation of the grade A during the study period.[10] Figure 1 presents a map of these villages along with the major towns, and the road network, which is

[10] Ninety-two villages had at least one sale of cocoa during the experiment. Since we are interested in looking at the relation between heterogeneity across markets of treatment effect on grade A prices and credit provision, we choose to conduct the analysis on villages with at least one sale of grade A. The results presented in section 3.2 are similar when using the sample of ninety-two markets with at least one purchase of any cocoa during the experiment (results are available on request).

unpaved. Panel A of Table 2 presents summary statistics from this sample of villages. On average, each village has 3.2 study traders, and 1.5 treatment traders. 34 of our 80 sample villages have at least one treatment and one control trader. This merits some concern about spillover effects between treatment and control. We address this concern directly in Section 3. As can be seen in Figure 1 the average road distance from a village to the nearest town is relatively short, at 9.6 miles using Dijsktra's minimum distance algorithm along the road network. Importantly, on average 65% of farmers selling to study traders have been given credit by at least one trader over the last year, highlighting the importance of interlinked transactions in this industry.

Randomization across traders randomly allocates treatment traders to sets of villages conditional on the number of study traders in the village. Since we will estimate heterogeneous treatment effects across villages, it is important to check whether villages are balanced in the composition of treatment and control traders. Panel B of Table 2 presents the coefficients of a regression of a village level covariate on the number of treatment traders and number of study traders as a test of balance. In all cases, the coefficient on the number of treatment traders are not statistically significant.

3 Experimental Results

In this section, we present the average treatment effect results from our experiment. We first document the negligible effect of the bonus on prices paid to farmers and show that the lack of price pass-through cannot be explained by increasing marginal costs of transport. We then show that the traders respond to the bonus by increasing credit provision to farmers. In section 5, we complement these results with an analysis of heterogeneous treatments across villages motivated by the theoretical framework we develop in section 4. Throughout the paper, the standard errors we report are robust to heteroskedasticity and are estimated with two non-nested clusters that allow for arbitrary correlation across observations from a given village, and across observations from a given trader. This clustering approach follows Cameron, Gelbach and Miller (2011).

3.1 Price Pass-Through

To study pass-through in prices, we estimate the following regression, where an observation is a shipment k delivered by trader i of randomization pair p, from village v in week t:

$$Price_{kivt} = \alpha_p + \tau_t + \theta^p(\text{Bonus}_i) + \mathbf{X}_i'\boldsymbol{\beta_x} + \mathbf{W}_v'\boldsymbol{\beta_w} + \epsilon_{kitv} \tag{1}$$

We include a number of variables to control for variation in the trader's expected resale price over time, which may itself affect the price paid to the farmer. The term α_p is a fixed effect for each matched pair in the randomization. Since pairs were matched within wholesalers, this effectively controls for the town in which the trader sells his cocoa. The term τ_t is a week fixed effect, to capture time varying factors in supply, such as weather, as well as any variation in the expectation of the wholesaler price that may fluctuate over time. The vector $\mathbf{X}'_i$, used in some specifications, includes the trader controls of baseline values of pounds of grade A sold, number of villages operating in, number of suppliers buying from, share of clients given credit in baseline, age, years of working with wholesaler, and dummies for ownership of a cement or tile floor, mobile phone and access to a storage facility. The vector $\mathbf{W}'_v$ includes the village-level covariates of baseline share of suppliers begin given credit, number of other bonus traders and number of study traders, miles to nearest town, and number of clients across all traders, and also five fixed effects for village chiefdoms, which are local units of legal and political administration. Bonus_i is a dummy equal to one if trader i is assigned to treatment, and so θ^P is the average treatment effect, conditional on the other controls. The term ϵ_{kitv} is an error. Pairwise randomization motivates the assumption that $E[\epsilon_{kitv}|\text{Bonus}_i, \alpha_p, \tau_t, \mathbf{X}'_i, \mathbf{W}'_v] = 0$, which ensures that θ^P is estimated without bias.

The term θ^p is the coefficient of interest. Recall that the bonus was Le. 150 per pound. If $\theta^p = 150$, we have perfect pass-through, as the treatment traders will have increased the price paid to farmers by the full amount that their resale price increased by. Table 3 presents estimates of θ^p. In the basic specification in column 1, which includes only randomization pair and week fixed effects, with no village or trader covariates, pass-through is statistically indistinguishable from zero, with a point estimate of $\theta^p = -5.4$ (s.e. = 14.9). Even at the upper bound of a 95% confidence interval, pass-through would be just 24 Leones, less than one fifth of the amount of the bonus, 150 Leones. This extremely low level of pass-through to farmgate prices is consistent with the evidence provided by Mitra et. al. (2013) and Fachamps and Hill (2008).[11]

Given that some villages contain both treatment and control traders, we are concerned that spillovers between groups may be driving this result. It may be that Bertrand style competition between treatment and control traders drives up the price offered by control traders within a village, so that there is no difference between the prices offered by both groups. We test this hypothesis directly by adding the number of other study traders and other treatment traders in column 2. If this were occurring, the number of other treatment traders in the village should

[11] Adhvaryu et al. (2013), in Tanzania, finds higher level of local price responsiveness to world price though still far from perfect pass-through.

raise prices independent of the effect of the treatment. We find little evidence of this, as the coefficient on this variable is small and statistically insignificant; even the upper bound of the 95% confidence interval is still very low (23 Leones).

There is also concern that low pass-through occurs because the trader with the bonus faces little competition from other traders with the bonus. In column 3, we test the hypothesis by testing whether pass-through is larger in villages with multiple treatment traders. In these villages, competition between treatment traders would potentially create more pass through, better approximating a price increase available to all traders in the village. To do this, we interact the two market level trader counts with the treatment status of the trader. This is a specification similar to the one developed to test for externalities by Kremer and Miguel (2004). The estimate of $\theta^p = -11 (s.e. = 19.5)$ can be interpreted as predicted pass-through in a village with no other treatment or control traders. We do find some evidence that treatment traders pay a higher price when there are other treated competitors in the market, but the coefficient on the interaction is not significant at standard levels. Even with multiple traders receiving the bonus, there is limited pass through in the market.

Column 4 uses both chiefdom fixed effects and the vectors of village-level and individual-level controls. Again the low pass-through result is robust. Column 5 presents the same regression using as our outcome an alternative measure of price taken by dividing a bag total expenditure by its weight. This provides reassurance that our price results are not driven by measurement error in prices. [12]

In a perfectly competitive model of spatial arbitrage, the difference in price between two locations that trade will equal the marginal cost of transport. A natural explanation for our lack of pass-through could be simply that marginal costs of transport are increasing rapidly for treatment traders. Table 4 presents estimates of equation (1), with outcomes related to cost in the place of $Price_{kivt}$, using all grades of cocoa shipped. In columns 1 and 2, we see that unit costs reported by the trader are also falling. In the preferred specification with chiefdom fixed effects and village and trader controls we have that the treatment effect is -8.4 Leones (s.e. = 2.1). This implies that in addition to the bonus of 150 Leones per unit, traders also received a gain in the form of lower transport costs per pound shipped. Finally columns 3 and 4, which

[12] In results not presented, we also tested for effects on the prices of B and C grade cocoa. Though we found no significant effect on the price of grade C cocoa, we did find a statistically significant effect on grade B prices (the point estimate is 37, which is still very far from perfect pass through). Field interviews suggest that this result is a result of Type I error on the part of traders, who observe quality imperfectly. The bonus has increased the expected price for grade A quality cocoa relative to grade B. Even if pass-through is zero for a given quality, if quality is imperfectly observable traders will now be more willing to pay the grade A price premium for cocoa that has some probability of being grade A.

amount to a linear probability model in which the outcome variable is a dummy indicating that a truck and not a motorcycle was used to transport the cocoa, show that this cost result is potentially driven by a change in transport technology. Trucks, on average, have consistently lower per unit costs. These results show that the lack of pass-through cannot be explained by increasing marginal costs.

3.2 Credit

To investigate the effect of the bonus on credit, we estimate the following regression, which is a modified version of (1):

$$Credit_{fiv} = \alpha_p + \theta^c(\text{Bonus}_i) + \mathbf{X_i'}\boldsymbol{\beta_x} + \mathbf{W_v'}\boldsymbol{\beta_w} + \nu_{\mathbf{fiv}} \tag{2}$$

An observation is a farmer. $Credit_{fipv}$ is an indicator of whether farmer f in village v was given credit by trader i of pair p during the course of the experiment (i.e. between September and December). The term θ^c is the treatment effect estimator, and ν_{fipv} is an error term. All other terms are as in (1). Pairwise randomization again motivates the assumption that $E[\nu_{fipv}|\text{Bonus}_i, \alpha_{ip}, \mathbf{X}_i', \mathbf{W}_v'] = 0$.

Table 5 presents estimates of the θ^c in equation (2). In column 1 we run a linear probability model where the outcome is a dummy equal to one if credit was provided to a farmer. The treatment effect on credit is substantial: farmers reported as regular suppliers by treatment traders in the baseline listing are 14 percentage points more likely to receive credit from these traders relative to a control mean of 12 percentage points. Columns 2 and 3 test for potential spillovers. The presence of other traders in the village, treatment or control, does not alter our results. Column 4 shows that the results are robust when adding chiefdom fixed effects, and trader and village controls. In column 5 we see the result in terms of Leones. Here, traders were asked after two months of treatment the amount of the loan last given to the farmer, if any was given in the past month. Farmers that did not receive any have values of this outcome equal to zero. We see that traders are raise their credit outlay by approximately 50%, with $\theta^c =$ Le. $9,771$ (s.e. = 5,209), off a control group mean of Le. 18,908.

In sum, we cannot reject that pass-through of the bonus in terms of prices is zero, but we find substantial average effects on credit provision to the farmers.

4 A Model of Pass-Through in Interlinked Transactions

In this section, we develop a simple model that describes the rate of price pass-through in the presence of interlinked transactions. The model draws from the broad theoretical literature on interlinkages.[13]. Most closely related is the work of Chaudhuri and Banerjee (2004), who endogenize the emergence of interlinked credit-product markets and study how these interlinkages respond to trade liberalization. We add to this framework strategic default considerations in the farmer-trader relation, and highlighting the relationship between credit responsiveness and price pass-through following a change in the price the trader receives.

The model makes three contributions that aid the interpretation of the empirical results. First, it generates the simple insight that the transaction price received by those transacting on a spot market differs from that of the farmers who are in the interlinked transaction contracts. In the latter, the price received is co-determined with the terms of a loan. The rate of price pass-through is then determined by the measure of people to whom the trader becomes willing to extend credit after the resale price has changed. There is a direct mapping here to the empirical results presented above. Our bonus expanded credit on the extensive margin—a greater number of farmers received credit. This effect can contribute to explain the low rate of price pass-through observed. We will test this conjecture in the next section by showing that it is precisely the markets in which credit pass-through is high that exhibit low price pass-through.

Second, the model generates additional testable predictions about the cross sectional variation of credit supply with other variables across markets. It describes the relation between credit provision and farmer prices, and determines the conditions under which the two will be negatively related across markets. The model also predicts that credit supply should be greater in markets where the return to giving credit for the trader is higher. In the model we allow for the returns to credit to vary along two dimensions, both of which are relevant in our setting. Traders are more likely to give credit when the number of traders in the market is greater and they have more to gain from a credit contract that "locks in" the farmer's produce and protects it from competition. Traders will also give more credit when the quantity of cocoa available per farmer is greater. We will verify both of these predictions in the Section 5.

Third, we contrast the welfare implications of this model with those of a benchmark model that does not account for interlinkages, showing that low price pass-through need not, as it does in the benchmark model, imply that farmers receive a low share of surplus relative to traders.

4.1 The Economy

Our economy is composed of M isolated markets. Each market m is populated by I_m farmers and J_m traders. Interactions between the two agents in each market can occur under two alternative contracts. In the *spot market*, the trader and farmer transact only at harvest time. This contract

[13] A helpful summary is given by Basu and Bell (1991

can be viewed as that which occurs in a benchmark model with no interlinkages. In *interlinked transactions* (ILT), a trader provides credit before harvest and then purchases output from the farmer at harvest, unless the farmer chooses to default.

Traders are homogeneous. Farmer i in market m is endowed with an amount of land, which varies across farmers within a market. If the farmer does not receive credit, the land produces a fixed quantity q_{im}, which we will write as q_i to reduce notation. If the farmer receives credit, the land is assumed to produce $q_i(1+r)$. In the limiting case of $r=0$, the credit relationship will still be valuable to both the farmer and trader for two reasons. In addition, the farmer receives some consumption smoothing benefit from the loan, and the trader can extract some of this benefit by lending. Field work suggests that credit plays both these roles, and so we allow for them all in the model. Because of these consumption benefits, all of the predictions discussed below obtain with $r=0$.[14] Finally, giving credit allows the trader to "lock in" the quantity produced by the farmer. Since strategic default on the loan is costly for the farmer, a trader that privides credit reduces the level of competition for cocoa from a given farmer.

We now discuss the payoff structure of the agents under the two types of contracts, spot market and ILT. Throughout, we assume farmers and traders are risk-neutral and maximize their expected profits.

4.1.1 The Spot Market

Spot market prices in market m, p_m^S, are equal to the wholesale price over a constant markdown,

$$p_m^S = \frac{w_m}{\mu}, \quad \mu \geq 1 \tag{3}$$

The markdown is a reduced form capturing trading costs proportional to value, price rigidity and any market power the trader may have. The utility of farmer i in market m transacting on the spot market is:

$$u_{im}^S = p^S q_i = \frac{w_m}{\mu} q_i \tag{4}$$

On the spot market, we assume that each trader has an equal probability to secure cocoa from a given farmer in market m equal to $1/J_m$. Therefore, the expected utility for trader j transacting with farmer i in market m is:

$$v_{jim}^S = \frac{1}{J_m}(w_m - p_m^S)q_i = \frac{1}{J_m}\frac{\mu-1}{\mu} w_m q_i \tag{5}$$

[14] We can also interpret output as quality-adjusted production. Credit allows farmers to increase quantity of a given quality by investing in post-harvesting processing, such as fermenting and drying. Such activity is costly, and so may require financing through credit.

4.1.2 Interlinked Transactions

In interlinked transactions, a trader provides credit before harvest, and subsequently purchases output at a pre-determined price. The contract stipulates a price, and the farmer's guarantee that the trader will receive all the farmer's produce once available. We assume that traders and farmers are randomly matched ex-ante and that only one trader can offer credit to a given farmer. In order to provide credit, the trader incurs a fixed cost f. This can be interpreted as the minimum amount of screening and monitoring that trader needs to undertake, independent of the amount of credit outlay (for a review of these issues, see Banerjee, 2002). We assume that if the two parties enter an interlinked transaction, the trader provides a fixed amount of credit per each bag denoted by c. In addition to the potential impact of credit on production levels if $r > 0$, we assume that the farmer also receives a utility benefit from the loan of $c_F = \lambda \cdot c$, with $\lambda > 1$. This is a reduced form for the increased utility of the farmer from extra pre-harvest consumption, which is assumed to be weakly larger than the trader utility cost of disbursing the loan.[15] One way to think about this is that the farmer experiences a higher marginal utility per unit of income in the pre-harvest season.

After receiving credit, the farmer decides whether to stick to the terms of the contract or to default. If the farmer respects the contract, he receives a farmer-specific contract price p^C_{im} and pays back the loan, c. We describe how this price is determined in equilibrium in section 4.2. When the farmer does not default, the utility of farmer i under ILT is

$$u^{CN}_{im} = (p^C_{im}(1 + r) + (\lambda - 1)c)q_i \tag{6}$$

and the utility for trader j in an ILT contract with farmer i is

$$v^{CN}_{jim} = ((w_m - p^C_{im})(1 + r))q_i - f \tag{7}$$

Note here that the trader's utility no longer includes the term $1/J_m$, since in the interlinked transaction contract, he is now certain to get the farmer's output (if the contract is enforced).[16]

The benefit of strategic default for the farmer depends on the underlying contracting institutions in market m. Specifically, we assume that, if the farmer defaults, he loses a share γ_{im} of his output. We do not consider partial default. After defaulting on the loan, he sells $(1-\gamma_{im})q_i(1+r)$ on the spot market. The parameter γ_{im} is broadly a measure of the quality of contracting institutions, capturing market characteristics that could shape the cost of default,

[15] We abstract from the investment optimization problem the farmer faces when receiving credit.

[16] An alternative interpretation of this setup, suggested to us by Chris Udry, is that the J traders in a given village form a cartel—hence the markdown μ—and that traders use credit as non-price, less visible tool to defect on the collusion agreement.

including the trader's monitoring costs, the reliability of local chiefs in enforcing contracts, and social norms specific to farmer i.

If he defaults, the utility of farmer i in the ILT contract is

$$u_{im}^{CD} = \left(p_m^S(1-\gamma_{im})(1+r)+\lambda c\right) q_i = \left(\frac{w_m}{\mu}(1-\gamma_{im})(1+r)+\lambda c\right) q_i, \tag{8}$$

and the utility of trader j matched to farmer i is

$$v_{jim}^{CD} = -c \cdot q_i - f \tag{9}$$

4.2 The Equilibrium Contract

Here we describe the conditions under which farmers and traders will opt to transact on the spot market or in an ILT contract. We also determine the equilibrium contract price under ILT. The timing of the game is as follows: in the first stage, the trader is randomly matched to the farmer, and decides whether to offer credit. He also decides the terms of the contract—the contract price at which output will be sold after harvest, p_{im}^C. If the trader does not offer credit, the farmer sells on the spot market. If the trader does offer credit, the game proceeds to the second stage and the farmer decides whether to accept or not. In the third stage, the farmer decides whether to default or not, conditional on having accepted the ILT. We solve the model by backwards induction and restrict our analysis to subgame-perfect Nash equilibria. In the third stage, the farmer decides not to default if

$$u_{im}^{CN}(p_{im}^C) \geq u_{im}^{CD}. \tag{10}$$

This is the farmer's incentive compatibility constraint, which highlights the fact that the decision to default depends on the proposed contract price, p_{im}^C. In order to prevent default, the trader must offer a large enough contract price to satisfy this inequality.

In the second stage, if the trader offers credit and a contract price in the first stage, the farmer must decide whether to accept it. The farmer accepts credit if

$$\max\left(u_{im}^{CN}(p_{im}^C), u_{im}^{CD}\right) \geq u_{im}^S. \tag{11}$$

This is the farmer's participation constraint.

In the first stage, the trader decides whether to offer credit and, if so, the contract price to offer. As is common in the principal-agent literature, we focus on the equilibrium in which the trader has all the bargaining power and sets the price so to maximize his profit conditional the farmer's incentive compatibility and participation constraints. The main comparative statics described in Section 4.3 however do not depend on this particular equilibrium selection.

The contract price will depend on which of the farmer's constraints bind, (10) or (11), which depends on the quality of contracting institutions. For low levels of γ_{im}, the farmer's incentive compatibility constraint binds, and the price must be set to ensure no default. Specifically this condition is $\gamma_{im} < \frac{r}{1+r} + \frac{c\lambda\mu}{w(1+r)} \equiv \hat{\gamma}_1$. For higher levels of γ_{im}, the farmer's participation constraint binds. Contract enforcement is so good that the farmer always prefers not to default once he accepts the loan, but the equilibrium price must be chosen high enough so that he accepts it in the first place. Given these conditions, we can summarize the price under the ILT contract as:

$$p_{im}^{C*} = \begin{cases} \frac{w_m}{\mu}(1-\gamma_{im}) + \frac{c}{1+r} & \text{if } \gamma_{im} \leq \hat{\gamma}_1 \\ \frac{w-(\lambda-1)c\mu}{\mu(1+r)} & \text{if } \gamma_{im} > \hat{\gamma}_1 \end{cases} \tag{12}$$

which is weakly decreasing in γ_{im}.

It is crucial to note the relationship between the contract price and the spot market price. When γ_{im} is above a minimal threshold $\hat{\gamma}_2 \equiv \frac{c\mu}{w(1+r)} < \hat{\gamma}_1$, the contract price, p_{im}^{C*} is smaller than the spot market price. It is under this condition that switching between the spot market and ILT could lower average transaction prices in the market. On the other hand, when $\gamma_{im} < \hat{\gamma}_2$ the trader needs to pay a price (weakly) larger than the spot market one to prevent strategic default. The trader is still willing to do so however because he is getting the benefit of additional quantity, either through increased production, or in expectation through the lock-in effect.

Finally, we consider the trader's participation constraint. Having now determined the optimal price, p_{im}^{C*}, the trader decides to offer credit to farmer i if

$$v_{jim}^{CN}(p_{im}^{C*}) \geq v_{jim}^{S} \tag{13}$$

Interlinked transaction contracts arise as the equilibrium contractual form if the inequality in equation 13 holds. In this equilibrium, the price in the interlinked transaction contract is described by Equation 12.

To build intuition for our empirical results, we now consider the case where farmers vary by their baseline production level, q_i but contract institutions vary only at the market level, denoted γ_m. The spot-market markdown μ, and the consumption smoothing benefit to the farmer λ are assumed to be constant across markets. Intuitively, traders provide credit only to those farmers whose quantities are large enough that the increase in trader revenues arising from credit provision more than offsets the fixed cost f. Specifically, farmer i and trader j in market m enter an ILT arrangement if $q_{im} > q_m^*$, where:

$$q_m^* = \begin{cases} \infty & \text{if } \gamma_m \leq \frac{cJ\mu-(J(1+r)-1)w(\mu-1)}{J(1+r)w} \equiv \hat{\gamma}_3 \\ \frac{fJ_m\mu}{w_m(J(1+r)-1)(\mu-1)+J(1+r)\gamma_m w_m - cJ_m\mu} & \text{if } \hat{\gamma}_3 < \gamma_m \leq \hat{\gamma}_1 \\ \frac{fJ_m\mu}{w_m(J-1)(\mu-1)+Jr\mu w_m - cJ_m(\lambda-1)\mu} & \text{if } \gamma_m > \hat{\gamma}_1 \end{cases}$$

In markets with very poor contracting institutions, and $\gamma_m \leq \hat{\gamma}_3$, no farmers receive credit. When the ILT does emerge, we observe that the minimum production volume a farmer needs to produce to access credit is decreasing in J_m, $(1+r)$, and is increasing in f. It is also decreasing in γ_m when $\hat{\gamma}_3 < \gamma_m < \hat{\gamma}_1$ and the farmer's incentive compatibility constraint binds. All of these results are intuitive; credit provision increases when the relative benefit for the trader from interlinked transactions increases. This occurs when: a) the number of competitors increases, raising the benefit of lock in; b) the productive returns to credit increase; c) the fixed cost from credit provision decreases; and d) the quality of contracting institutions increases, and thus the contract price the trader has to offer to induce no-default falls. In equilibrium, the contractual form preferred by the trader determines the price each farmer pays. Farmer i sells on the spot market sell at $p_{im} = p^S_m$, and farmers in an ILT sell at $p_{im} = p^{C*}_{im}$

4.3 Pass-Through

We now study the impact on transaction prices of an increase in the wholesale price at which the trader can resell the output bought from farmer, w_m. We continue to assume that q_{im} is the only parameter varying across farmers in a given market, and that μ and λ are constant everywhere. We also continue to assume that γ_m is constant within a market, but the insights of the analysis are identical if we relax this assumption.

The relative profit for the trader of transacting under interlinked transaction rather than spot markets, $v^{CN}_{jim} - v^S_{jim}$ is increasing in w_m. As the trader has higher returns from purchasing cocoa, the return from giving credit increases. Those farmer-trader pairs for which the difference changes from negative to positive will switch from spot market to interlinked transactions. The transaction price for farmer i in market m is now summarized by

$$p_{im} = \begin{cases} p^S_{im} & \text{if } q_{im} < q^*_m(w_m) \\ p^{C*}_{im} & \text{if } q_{im} \geq q^*_m(w_m) \end{cases}$$

Consider explicitly how p_{im} changes in response to a change in w_m from w^0_m to $w_m = w^0_m + \Delta$, where Δ is some positive constant. We restrict our attention to the case in which the contract price is determined by the farmer's incentive compatibility constraint: $\gamma_m \leq \hat{\gamma}_1$. The results are similar for higher values of γ_m. The direction and the magnitude of the change for a given farmer depends on whether the farmer is on the spot market, in an ILT, or whether the farmer switches into ILT in response to the change in w_m. There are three cases:

1. Farmers who remain on the spot market experience an increase in their price, p^S_m, of $\frac{\Delta}{\mu}$.

2. Farmers who were in ILT contracts both before and after the change in w_m experience an increase in their contract price, p^C_{im}, of $\frac{\Delta(1-\gamma_m)}{\mu}$.

3. Farmers who enter an ILT contract in response to the increase in w_m face the following change in price: $\frac{\Delta(1-\gamma_m)-\gamma_m w_m^0}{\mu} + \frac{c}{1+r}$. If $\gamma_m \geq \hat{\gamma}_2$, farmers that switch into ILT in response to the change experience a *decrease* in price as they switch from the spot price to the contract. They are however still better off, because they are now receiving credit. If $\gamma_m < \hat{\gamma}_2$, switching farmers experience an increase in price as they can threaten strategic default. Traders are however still better off because they are receiving more cocoa in expectation.

The overall rate of price pass-through is thus ambiguous. In markets with $\gamma_m > \hat{\gamma}_2$ and a large measure of people near the cut off quantity for credit, average pass-through in the market may be reduced substantially, as farmers switch from the spot market contract to ILT. Average prices may even fall. We summarize these results, and their implications for farmers' welfare in the next subsection.

This theoretical analysis of a change in the world price also provides guidance to interpret our experiment in the context of the model. While the randomization of the bonus allowed us to introduce the required variation to study price and credit responsiveness with transaction-level data, it is important to highlight some differences relative to a world price change. The main departure from the above comparative statics is that not every trader in the market receives this higher price. Therefore, one would expect the spot market price adjustment that occurs in response to the experimental variation to be lower than in the case where every trader is treated. However, the main insight of the comparative statics that the average farmer price response depends on how the equilibrium contract (i.e., spot market vs. interlinkages) changes when trader prices go up holds even when the treatment traders resale price is higher than the one in the rest of market. In addition, Table 3 showed that, on average, the price response is very limited even when there are several traders treated in the same market.[17], a scenario which is closer to a change in the world price (i.e. a change that affects all traders).

Another potential difference between our experimental variation and a change in the world price could be the transitory nature of the trader price shock. Traders may display larger price responses when they expect their prices to shift permanently. Two factors mitigate this potential discrepancy between the experiment and a change in world price. First, uncertainty also concerns fluctuations in world price: sharp reductions have often followed price increases in the last decade. Second, the trader bonus was "permanent" in the sense that the wholesalers annouced it was going to last roughly until the end of the season.

[17]Prices paid by treatment traders go up when there are other treated traders in the market, but this effect is small and non-significant.

4.4 Welfare Analysis With and Without Interlinkages

Here we contrast a welfare analysis of pass-through in our model with one in a model without interlinkages. Though any precise welfare calculation would depend crucially on our functional form assumptions, the analytic comparison is instructive. It emphasizes the point that in the presence of interlinkages, it is not immediate from a low level of pass-through that farmers gain little from an increase in the wholesale price.

We now assume that q_{im} is distributed according to a cumulative distribution function $G(q_{im})$ with bounded support $[q_{Lm}, q_{Hm}]$. We restrict our analysis to the case in which $q^*_m(w_m) \in [q_{Lm}, q_{Hm}]$, and both spot markets and ILT transactions occur in the market. Consider first a benchmark model in which farmers only transact on the spot market. Average welfare is given by

$$W^S = \int_{q_L}^{q_H} q \frac{w}{\mu} g(q) dq, \tag{14}$$

and the change in average welfare in response to a change in wholesale price is

$$\frac{dW^S}{dw} = E[q] \frac{1}{\mu} \tag{15}$$

Equation (15) shows that, in the absence of credit provision, one can simply recover the trader markdown $\frac{1}{\mu}$ from the price pass-through estimates.[18] This model then yields the intuition that low pass-through implies farmers receive on average a relatively smaller share of wholesale value than do the traders.

In our model, which accounts for interlinkages, average farmer welfare in the market is equal to:

$$W^{ILT} = \int_{q_L}^{q^*} q \frac{w}{\mu} g(q) dq + \int_{q^*}^{q_H} q \left((1+r)\left(\frac{(1-\gamma)w}{\mu} + \frac{c}{1+r}\right) + (\lambda - 1)c \right) g(q) dq, \tag{16}$$

which is simply a weighted average of the welfare of farmers under the spot market and ILT contracts. The first term represents the welfare of farmers transacting on the spot market and the second is the welfare for farmers who are in ILT contracts. To find the average welfare effect of an increase in the wholesale price w, we apply Leibniz's rule to obtain

$$\begin{aligned} \frac{dW^{ILT}}{dw} &= G(q^*) E[q|q < q^*] \frac{1}{\mu} + (1 - G(q^*)) E[q|q \geq q^*] \frac{(1+r)(1-\gamma)}{\mu} \\ &\quad - \left(\lambda c - (1+r)\gamma \frac{w}{\mu} \right) q^* g(q^*) \frac{dq^*}{dw} \end{aligned} \tag{17}$$

[18] This simple result obviously relies on the assumption of perfectly inelastic supply at the farmer level. In the case with elastic supply, pass-through will be determined jointly by the markdown and the supply elasticity.

Intuitively, the change in welfare is the sum of three terms: a) the average change in welfare for farmers on the spot market, weighted by the share of farmers on the spot market; b) the average change in welfare for farmers on ILT contracts, weighted by the share of farmers in ILT; c) the change in welfare for farmers that switch into ILT in response to the change in welfare. Notice that $\frac{dq^*}{dw} < 0$, and so the last term is positive.

The difference between (17) and (15) depends crucially on the quality of contracting institutions and the density of people near the cut off. It is very possible that price pass-through could be very low, and yet the change in farmers' welfare be high. Similarly, the price pass-through alone does not allow one to recover the markdown rate μ.

Quantifying the welfare effects of the experiment is beyond the scope of the paper. One would need farmer-level estimates of the degree of farmer liquidity constraints in production, of the marginal utility of consumption across different seasons, and of the cost of default on loan contracts. The goal of the simple analyis we presented above is to show that, in the presence of interlinkages, both price and credit response shape how farmer welfare responds to a change in wholesale prices. Propagation of incentives along the value chain is likely to be underestimated when one only focuses on transaction prices. This is particularly relevant in the case of a negative correlation between credit and price responses, which we document in the next section.

5 The Substitutability of Price and Credit Pass-Through

We now summarize the core predictions of our model:

1. The share of farmers receiving credit is positively related to the average quantity of cocoa available per farmer in the market, and the number of other traders competing in the market.

2. If $\gamma_m > \hat{\gamma}_2$,

    (a) Across villages, the average transaction price is *negatively* correlated with the share of farmers receiving credit.

    (b) The change in transaction price in response to a change in w_m is *lower* in markets in which the extensive margin response of credit supply to the change is larger.

3. If $\hat{\gamma}_3 < \gamma_m < \hat{\gamma}_2$,

    (a) Across villages, the average transaction price is *positively* correlated with the share of farmers receiving credit.

(b) The change in transaction price in response to a change in w_m is *higher* in markets in which the extensive margin response of credit supply to the change is larger.

Average transaction price could be in principle positively correlated with the prevalence of interlinked transactions if contracting institution quality are low enough that the trader, while still benefiting from the lock-in effect or from the increased quantity, needs to increase the price to avoid farmer strategic default. On the other hand, when contracting institutions are high enough, prices will be negatively correlated with the prevalence of interlinked transactions. Whether the farmer price response to a change in the wholesale price is higher or lower in markets with high credit responsiveness also depends on which of the two cases holds.

We test first prediction 1 and distinguish between 2a and 3a using our baseline data. Table 6 presents these results. Each column shows the coefficients from a cross-sectional regression of a village level outcome on other village level covariates and a constant. These indicators come from the pre-treatment period, when our inspectors were collecting data on quantity, prices, and quality of cocoa delivered to wholesalers, but treatments had not been assigned. Column 1 examines first the correlates of credit supply; the outcome here is the village-level share of farmers receiving credit from study traders. This outcome is positively and significantly correlated with the cocoa available per farmer, which is simply the quantity of cocoa delivered from that village in the pre treatment period divided by the number of farmers. This result is consistent with the model's prediction that traders are more likely to extend credit to villages from which they can get higher volumes of cocoa per farmer. In addition, village-level credit share is also positively (and significantly) correlated with the number of traders in the economy. This confirms our intuition about the "lock-in" effect. Controlling for available quantity, credit is more likely to be provided in markets with more competition.

Column 2 of Table 6 tests directly between predictions 2a and 3a, on the relationship between credit supply and average prices of grade A cocoa. The number of observations here is lower, because the pre-treatment period lasted long enough to observe prices from only a subset of villages. The estimates here show that moving from zero credit share to full credit share decreases the price paid conditional on quality by 137 Leones (s.e. = 74.6). This result suggests that contract enforcement is indeed good enough that traders can pay a lower prices relative to spot markets when entering an interlinked transaction contract (e.g. the condition $\gamma_m > \hat{\gamma}_2$ holds on average). Finally, column 3 shows that the ratio of the volume of high quality cocoa and the total volume of cocoa produced in the village is increasing in the level of credit provision.

We next test between predictions 2b and 3b using variation created by our experiment. We modify equation (2) to allow for heterogeneous treatment effects across villages by specifying the regression equation:

$$Credit_{fipv} = \alpha_{ip}+\theta^{C}(\text{Bonus}_i)+(\text{Bonus}_i\times\mathbf{W}'_v)\boldsymbol{\theta^{C}_{w}}+\mathbf{W}'_v\boldsymbol{\beta_{w}}+(\text{Bonus}_i\times\mathbf{X}'_{\mathbf{i}})\boldsymbol{\theta^{C}_{x}}+\mathbf{X}'_{\mathbf{i}}\boldsymbol{\beta_{x}}+\nu_{\mathbf{fipv}} \quad (18)$$

where, as before, $\mathbf{W}_v$ is the vector of village covariates and $\mathbf{X}_i$ is a vector of trader level covariates. For any trader-village pair iv then we have an estimator for the credit response $\widehat{TE}^{c}_{iv} = \mathbf{W}'_v\boldsymbol{\theta^{c}_{w}} + \mathbf{X}'_i\boldsymbol{\theta^{c}_{i}} + \theta^{c}$. Finally, we run the following specification to test whether pairs with higher credit pass-through display lower price treatment effect:

$$Price_{kipvt} = \alpha_{ip} + \tau_t + \theta^{p}(\text{Bonus}_i) + \theta^{p}_{c}(\widehat{TE}^{c}_{iv}\cdot\text{Bonus}_i) + \mathbf{X}'_i\boldsymbol{\beta_{x}} + \mathbf{W}'_v\boldsymbol{\beta_{w}} + \epsilon_{kiptv}, \qquad (19)$$

Substitutability across pass-through margins predicts that $\theta^{p}_{c} < 0$.[19]

Table 7 presents estimates of θ^{p}_{c}. In the different columns we show estimates generated using different sets of controls to predict $\widehat{TE}^{c}_{iv}$. Any test of significance in equation (19) must account for prediction error in the treatment effect on credit. To do so, we follow the recommendations of Bertrand, Duflo, and Mullainathan (2004) and Cameron, Gelbach, and Miller (2008), and present p-values for a Wald test against the null hypothesis that $\theta^{p}_{c} = 0$ calculated using the pair cluster bootstrap-t procedure of Efron (1981). Bootstrap clusters are defined at the village level.[20]

Our estimates of θ^{p}_{c} are negative and statistically significant at conventional levels in each of the specifications. In column 1, $\widehat{TE}^{cN}_{iv}$ is predicted using only chiefdom dummies. Chiefdoms are local geographic units of legal and political administration, and, as discussed in Acemoglu, Reed and Robinson (2013), a plausible proxy for variation in contract enforcement institutions. The estimate using these dummies predicts that a village where the bonus raised the likelihood of credit provision to farmers by 14 percentage points—the mean treatment effect in Table 5—would display a price response 46.2 Leones lower than a village with no effect of the bonus on credit. This is economically relevant as it accounts for a reduction of pass-through by about 1/3 relative to perfect pass-through.[21] We find similar results in column 2, where the effect

[19] We note that the estimated village-level treatment effect on credit, $\widehat{TE}^{c}_{iv}$, is collinear with the vector of controls and thus cannot be included in the estimating equation.

[20] Specifically, we first estimate $\hat{\theta}^{p}_{c}$ on the full sample and generate a T-statistic, T_0 from a Wald test of the null hypothesis that $\theta^{p}_{c} = 0$. We then draw with replacement a sample of villages 1,000 times. For each draw, we predict $\widehat{TE}^{cN*}_{iv}$ and then use it to estimate another $\hat{\theta}^{p*}_{c}$, where the star indicates the bootstrapped sample. We then generate a test statistic T^{*} from a Wald test of the hypothesis that $\hat{\theta}^{p*}_{c} = \hat{\theta}^{p}_{c}$ using the standard error from the bootstrap estimate. We hold this test statistic in memory. After 1,000 draws, a p-value is calculated from (twice the) position of T_0 in distribution of test statistics T^{*}.

[21] Recall that perfect pass-through of the bonus would imply pass-through of 150.

on credit is predicted using chiefdom dummies and village covariates, and in column 3, where we add trader covariates into the prediction of the credit effect. While the precise magnitude of these results may vary across specifications, the core result is confirmed: price and credit pass-through are substitutes. In villages in which traders respond to a wholesale price increase by raising credit supply to the farmers, price pass-through will be lower.

As we mentioned in Section 2.3, one could be concerned about traders misreporting price and credit data. Treatment or control traders may over-report figures in order to continue receiving the bonus or gain access to it, respectively. First, this is unlikely given that traders were informed that the experiment would run for the whole harvest season. Second, the stark difference in measured credit and price treatment effects is not consistent with either of the two misreporting stories. Third, misreporting cannot explain the evidence about the substitutability of the credit and price response margins we presented earlier in this section.

6 Concluding Remarks

The theory and evidence presented in this paper show that, in the presence of interlinked transactions, low price pass-through may obscure other channels, in particular credit, through which value is passed from buyers to producers. The presence of interlinked transactions is thus a candidate explanation for the low rates of price pass-through that have been observed elsewhere in developing economies, and in a wide variety of other contexts. Further, we show that an industry in which agents in the supply chain play an important role in providing credit, credit supply can be highly responsive to product market conditions.

These results have broad implications. Interlinked transactions along the value chain are common in developing economies and we expect our results to be particularly valuable in these settings. More broadly, interlinkages play a role in a wide range of transactions. For instance, trade credit is a major source of finance for firms internationally (Petersen and Rajan, 1997; Fisman and Love, 2003) and cash-in-advance plays an important role in international trade contracts (Antràs and Foley, 2011). Our work shows that measuring the adjustment along the margin of finance provision will be important for understanding both how incentives are transmitted along the supply chain in these contexts, and how welfare is split between producers and traders.

In addition, the paper leaves several other questions open for further research. In particular, the question of how changes in credit supply driven by the product market conditions faced by intermediaries affects production decisions, particularly in agriculture, is an exciting one for future research. Results there would have important implications for policy makers interested in improving farmers' welfare and overall surplus, and help to better understand the trade-off between policies aimed at reducing markdowns charged by traders, and those aimed at improving the enforcement of contracts.

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Figure 1: Map of study villages

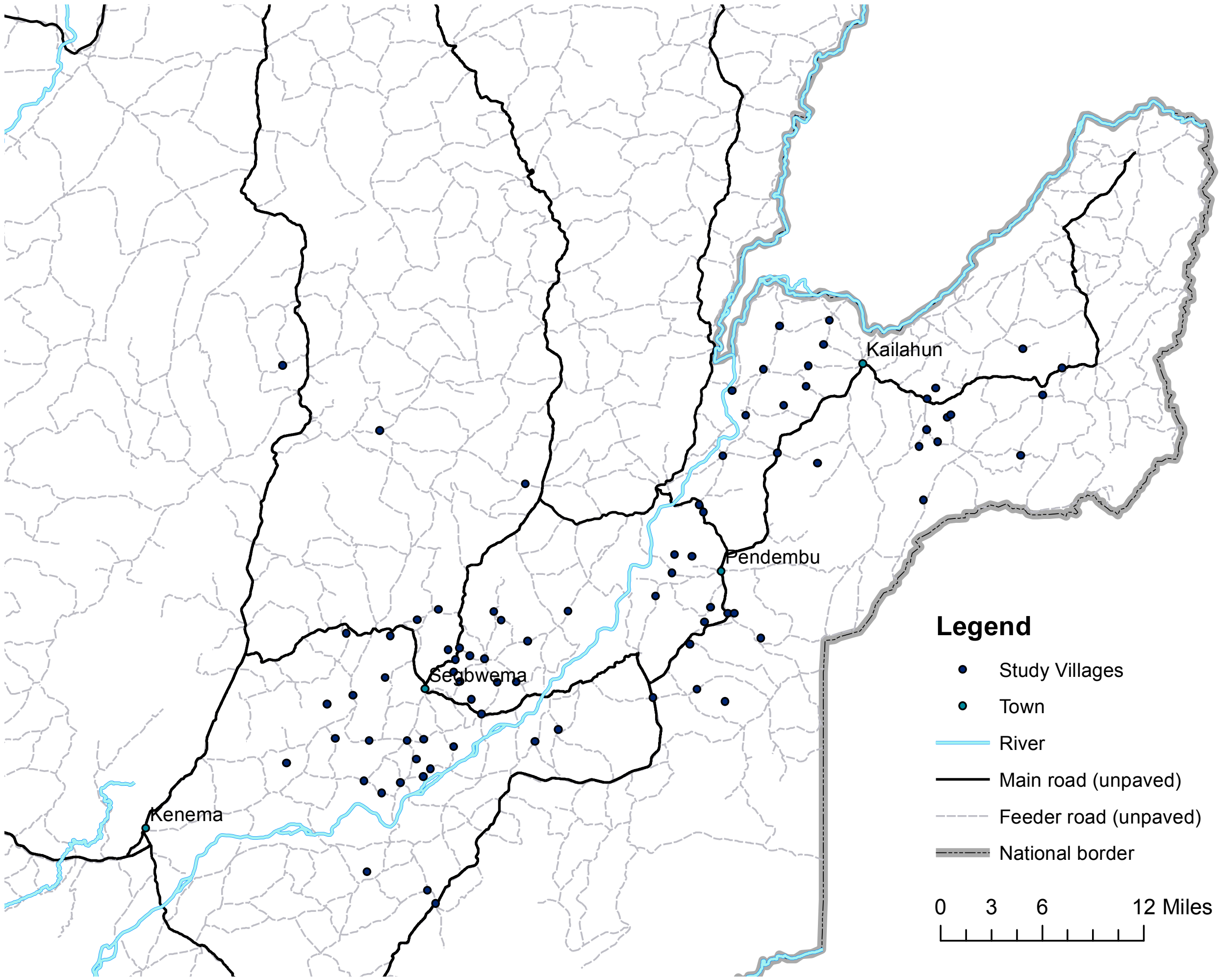

Table 1: Trader summary statistics

Covariate	Treatment	Control	Treatment - Control
Panel A: Baseline Interview			
Self-estimate bags sold in 2011	32.8	30.3	2.5
			(6.7)
Self-estimate grade A bags sold in 2011	20.0	18.6	1.4
			(5.4)
Age, years	38.2	36.9	1.3
			(2.1)
Years selling to study wholesaler	5.7	7.3	-1.4
			(1.1)
Cement or tile floor in house $\in \{0,1\}$	0.53	0.62	-0.09
			(0.1)
Mobile phone owner $\in \{0,1\}$	0.90	0.93	-0.03
			(0.06)
Access to storage facility $\in \{0,1\}$	0.88	0.78	0.10
			(0.09)
Panel B: Pre-treatment shipment data			
Cocoa (pounds) sold during pre-treatment	2,478	2,594	117
			(673)
Grade A (pounds) sold during pre-treatment	639	1,022	-382
			(380)
Per pound farmer price for Grade A (Leones)[a]	3,120	3,165	-45
			(55)
Per pound farmer price for Grades B or C (Leones)[b]	3,066	3,050	16
			(30)
Panel C: Baseline farmer listing			
Villages operating in	4.87	4.25	0.62
			(0.41)
Number of farmers buying from	18.7	20.5	-1.8
			(3.1)
Mean number of farmers per village	5.6	5.8	-0.2
			(0.8)
Share of farmers given credit since March	0.688	0.694	-0.006
			(0.0704)
Number of observations	40	40	

Notes: Standard errors allowing for unequal variance between groups in parenthesis. Treatment and control assigned randomly within pair of matched on self-estimates of grade A bags sold in 2011.[a] There are only 22 treatment observations of the grade A price in pre-treatment shipments, and 24 control.[b] There are only 30 treatment observations of a grade B or C price in pre-treatment shipments, and 34 control.

Table 2: Village summary statistics

Village covariate	# of study traders	# of treatment traders	Miles to nearest town	Baseline credit share	Total farmers reported by traders
Panel A: Sample averages					
Mean	3.2	1.5	9.6	0.65	18.7
	(2.4)	(1.5)	(5.7)	(0.29)	(16.4)
Number of observations	80	80	80	80	80
Panel B: Balance in count of treatment traders across sample villages					
# of treatment traders			0.79	0.01	0.02
			(0.66)	(0.03)	(1.50)
# of study traders			-0.28	0.02	5.24
			(0.41)	(0.02)	(1.03)
Number of observations	80	80	80	80	80

Notes: Panel A shows means of study sample of villages with standard deviations in parenthesis. Panel B shows the coefficients in a regression of the covariate (the column header) on the number of treatment traders, the number of study traders and a constant. Robust standard errors are presented in parentheses in panel B. Miles to nearest town calculated using Dijkstra's minimum distance algorithm along the network of rural feeder roads. Baseline credit share and total number of clients reported in a baseline listing of all clients in each village.

Table 3: Farmer price response

	(1)	(2)	(3)	(4)	(5)
Price	Grade A	Grade A	Grade A	Grade A	Grade A (alt.)
Bonus	-5.4	-5.5	-11.0	-7.0	-3.6
	(14.9)	(13.8)	(19.5)	(13.2)	(15.1)
# Other bonus traders		8.8	3.3	7.3	
		(7.4)	(10.0)	(7.0)	
(Bonus × # Other bonus traders)			7.7		
			(10.7)		
# Other traders		-10.7*	-9.8	-4.3	
		(5.7)	(7.4)	(6.1)	
(Bonus × # Other traders)			-1.6		
			(6.6)		
R^2	0.90	0.90	0.90	0.91	0.89
Number of observations	1,090	1,090	1,090	1,071	1,090
Chiefdom fixed effects	NO	NO	NO	YES	NO
Village controls	NO	NO	NO	YES	NO
Trader controls	NO	NO	NO	YES	NO

Notes: Robust standard errors in parenthesis allow for two-way, non-nested clustering at the village and trader level. All specifications include calendar week and randomization pair fixed effects. An observation is a shipment delivered to a wholesaler, and prices are per pound in Leones. Bonus is a dummy for whether the trader recieved an increase in the resale price of 150 Leones per pound for grade A only, and so perfect pass-through would imply a coefficient of 150 on the bonus indicator in columns 1, 2, 4 and 5. There were approximately 4,000 Leones to the U.S. dollar at the time of the study. The alternative measure of price in column 5 is the total price paid to the farmers divided by weight of shipment. Trader controls are baseline values of pounds of grade A sold, number of villages operating in, number of suppliers buying from, share of clients given credit in baseline, age, years of working with wholesaler, and dummies for ownership of a cement or tile floor, mobile phone and access to a storage facility. Village controls are baseline share of suppliers begin given credit, number of other bonus traders and number of study traders, miles to nearest town, and number of clients across all traders. Trader and village controls are summarized in Tables 1 and 2, respectively. *** $p<0.01$, ** $p<0.05$, *$p<0.1$

Table 4: Transport cost and technology choice response

Variables	(1) Unit cost	(2) Unit cost	(3) Truck use	(4) Truck use
Bonus	-11.9***	-8.4***	0.20***	0.21***
	(3.5)	(2.1)	(0.06)	(0.04)
R^2	0.49	0.57	0.49	0.53
Number of observations	1,089	1,070	1,089	1,070
Chiefdom fixed effects	NO	YES	NO	YES
Village controls	NO	YES	NO	YES
Trader controls	NO	YES	NO	YES

Notes: Robust standard errors in parenthesis allow for two-way, non-nested clustering at the village and trader level. All specifications include calendar week and randomization pair fixed effects. An observation is a shipment delivered to a wholesaler. Bonus is a dummy indicating a treatment trader. Costs in columns 1 and 2 are per pound in Leones, with a control group mean (s.d.) of Le. 47 (29); truck use in columns 3 and 4 is a dummy indicating whether a hired truck was used for transport, with a control group mean of 0.39. There were approximately 4,000 Leones to the U.S. dollar at the time of the study. Trader controls are baseline values of pounds of grade A sold, number of villages operating in, number of suppliers buying from, share of clients given credit in baseline, age, years of working with wholesaler, and dummies for ownership of a cement or tile floor, mobile phone and access to a storage facility. Village controls are baseline share of suppliers begin given credit, number of other bonus traders and number of study traders, miles to nearest town, and number of clients across all traders. Trader and village controls are summarized in Tables 1 and 2, respectively. *** p<0.01, ** p<0.05, *p<0.1

Table 5: Credit response

Variables	(1) Lent	(2) Lent	(3) Lent	(4) Lent	(5) Amount lent
Bonus	0.14***	0.14***	0.11*	0.13***	9,771*
	(0.03)	(0.03)	(0.07)	(0.03)	(5,209)
# Other bonus traders		-0.01	-0.00	-0.01	
		(0.01)	(0.02)	(0.01)	
(Bonus × # Other bonus traders)			-0.01		
			(0.02)		
# Other traders		0.01	0.00	0.01	
		(0.01)	(0.01)	(0.01)	
(Bonus × # Other traders)			0.01		
			(0.02)		
R^2	0.31	0.31	0.31	0.35	0.57
Number of observations	1,541	1,541	1,541	1,529	1,541
Chiefdom fixed effects	NO	NO	NO	YES	NO
Village controls	NO	NO	NO	YES	NO
Trader controls	NO	NO	NO	YES	NO

Notes: Robust standard errors in parenthesis allow for two-way, non-nested clustering at the village and trader level. All specifications include calendar week and randomization pair fixed effects. An observation is a farmer listed by the trader in the baseline. The dependent variable in columns 1-4 is an indicator for whether the trader lent any money to the farmer during the duration of the experiment. The control mean of this dummy was 0.12. The dependent variable in column 5 is the amount lent in Leones during the last month of the experiment. The control mean of this amount was Le 18,908 (s.d. = 52,597). Trader controls are baseline values of pounds of grade A sold, number of villages operating in, number of suppliers buying from, share of clients given credit in baseline, age, years of working with wholesaler, and dummies for ownership of a cement or tile floor, mobile phone and access to a storage facility. Village controls are baseline share of suppliers begin given credit, number of other bonus traders and number of study traders, miles to nearest town, and number of clients across all traders. Trader and village controls are summarized in Tables 1 and 2, respectively. *** p<0.01, ** p<0.05, *p<0.1

Table 6: Substitutability, baseline correlations

Variables	(1) Baseline credit share	(2) Price per lb.	(3) Share of grade A
Pounds of cocoa per farmer	0.09***		
	(0.03)		
Number of study traders	0.03**	-3.8	-0.02*
	(0.01)	(7.6)	(0.01)
Miles to nearest town	0.00	-3.3	0.00
	(0.00)	(2.9)	(0.01)
Baseline credit share		-137.0*	0.34**
		(74.6)	(0.14)
R^2	0.07	0.09	0.11
Number of observations	125	44	75
Dependent variable mean	0.27	3,147	0.29

Notes: An observation is a village. Robust standard errors in parenthesis. The number of observations changes across columns because during the pre-treatment period, price and grade data are available for only the subset of the villages from which cocoa was delivered in that period. In particular, traders brought cocoa bags from only 75 villages and grade A cocoa from only 44 villages during the pre-treatment period. *** p<0.01, ** p<0.05, *p<0.1

Table 7: Substitutability of Pass-Through Margin

Variables	(1) Price	(2) Price	(3) Price
(Bonus × estimated effect of bonus on credit)	-330.09	-256.49	-182.71
	[.014]	[.006]	[.008]
R^2	0.91	0.91	0.91
Number of observations	1,069	1,069	1,069
Chiefdom fixed effects	YES	YES	YES
Village controls	NO	YES	YES
Trader controls	NO	NO	YES

Notes: Each column presents estimates of θ_c^p from equation 19. P-values in brackets are derived from pairs cluster bootstrap-t at the village-level using 1,000 replications. Trader controls are baseline values of pounds of grade A sold, number of villages operating in, number of suppliers buying from, share of clients given credit in baseline, age, years of working with wholesaler, and dummies for ownership of a cement or tile floor, mobile phone and access to a storage facility. Village controls are baseline share of suppliers begin given credit, number of other bonus traders and number of study traders, miles to nearest town, and number of clients across all traders. Trader and village controls are summarized in Tables 1 and 2, respectively.

A Appendix: Cocoa Quality

Both international and local cocoa prices vary with quality. Factors contributing to poor quality cocoa are high moisture content, mold, germination, a lack of fermentation and slate, a discoloration signaling poor flavor. There is wide agreement on these standards internationally. For a discussion see CAOBISCO (2002) and for a manual specific to West Africa on how to improve cocoa at the farm level see David (2005). Other dimensions of quality affecting price on the international market are various fair-trade and environmental certifications. Such certification generally requires that beans can be verifiably traced to individual producers. In our market, there is not yet the infrastructure to do such tracing, and so this quality dimension does not apply.

Table A.1 shows the average quality and wholesale prices of cocoa bags from the experiment, before the November fall in the international price. As can be seen, moisture content has the highest price elasticity—price falls by 0.32% with a one percentage point increase in moisture. Moisture is an important variable in our market, because wet cocoa rots in storage, destroying value. At an average 11% moisture content, cocoa in our market is substantially wetter than export grade, which requires a maximum moisture content of 7%. For this reason, many exporters maintain large drying facilities. There is an efficiency cost to this organizational structure, as some cocoa that is not dried at the farm gate will be lost to rot in transport.

In our grading system, inspectors from our research team with local language skills stayed in the warehouses of wholesalers and tested a sample of 50 beans from each bag of cocoa as it arrived. Moisture was measured using Dickey John MiniGAC moisture meters, two of which were generously donated by the manufacturer. Other defects were spotted by eye, after cracking beans open with a knife. Grade A beans have no more than average 11.5% moisture, no more than 2% mold (1 bean of 50), and no less than 72% beans with no defect (36 beans of 50). Grade B beans have no more than 22% moisture, 4% mold (2 beans of 50) and no less than 52% good beans (27 beans of 50). Grade C applies to any bean failing to be grade A or B. At baseline, quantities supplied by traders were approximately one third of each.

Table A.1: Appendix, Cocoa Quality

Defect	Average per shipment	Price elasticity	Average per pound price by tercile of defect (Le.) 1	2	3
Moisture Content	11%	-0.32%	3,384	3,297	3,263
Mold	2%	-0.02%	3,308	3,353	3,241
Germinated	3%	-0.01%	3,309	3,313	3,298
Under-fermented	15%	-0.02%	3,345	3,333	3,228
Slate	7%	-0.01%	3,323	3,304	3,279

Notes: Data from 916 treatment and control transactions. Elasiticty gives the percentage reduction in price for a 1 percentage point increase in the defect.