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Incomplete Pass-Through and Interlinked Transactions*

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Abstract

Transactions in which buyers provide credit or other services to producers in addition to buying output are common in developing countries. Output prices are determined in part by the terms of these other transactions. We present results from a randomized controlled experiment designed to study the multiple margins through which value is passed from traders to agricultural producers. Consistent with other studies, we find limited price pass-through in response to an increase in the trader resale price. However, there is a large response in credit provision. We develop a model of interlinked transactions that highlights the substitutability of price and credit pass-through across markets, and verify its predictions empirically. Calibration suggests that to ignore margins of pass-through other than price has substantial implications for welfare analysis.

JEL Classification: D60, F10, O17, Q13, Q14

Keywords: Pass-through, interlinked transactions, intermediated trade, agricultural markets, pair-wise randomization.

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1 Introduction

The rate at which prices pass through a supply chain from end buyers to producers is of central importance for economic development, as it is producer prices, along with costs, that ultimately determine investment and the decision to adopt technologies. The benefit to growth offered by trade liberalization, for instance, may be attenuated to the extent that international price signals fail to reach domestic producers. A literature in international economics (eg. Feenstra, 1989, and Goldberg and Hellerstein, 2008) points to imperfect competition as an important determinant of the pass-through rate. A more recent literature (Fabinger and Weyl, 2013; Atkin and Donaldson, 2012) uses the pass-through rate as a tool to infer the shares of surplus captured by producers, consumers and intermediaries in the economy.

The frameworks used in the works above, however, do not consider other channels through which value is passed from end buyers to producers in a broad class of transactions common in developing economies. As highlighted by a long literature in development economics (e.g. Bardhan, 1980, Braverman and Stiglitz, 1982, Bell, 1988, Grosh, 1994, Poulton, Doward and Kydd, 1998, Deb and Suri, 2012) transactions in these economies—frequently in the agricultural sector—are often interlinked. Intermediaries not only buy output, but they also supply producers with credit and inputs. The terms of the output transaction are determined jointly with the terms of the credit or input relation. In the presence of such interlinkages, the rate of price pass-through is not sufficient to infer the benefit producers derive from a change in the end buyers' price; one must also take into account pass-through on other margins, for instance in the credit outlay, or the prices of inputs supplied. In this paper, we show that these effects can be first order, and that the presence of interlinked transactions can have substantial effects on the pass-through rate. Our work thus complements the work described above, by extending the pass-through framework for analyzing welfare to a broader class of transactions.

Our paper makes three contributions. First, we run a randomized experiment in a set of agricultural markets in sub-Saharan Africa, specifically in the cocoa industry of Sierra Leone. In the experiment we pay treatment 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.

Second, we develop a simple theoretical model in which changes in the price paid to intermediaries for a good shifts the share of producers engaged in interlinked transactions relative to those 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. This credit is paid back in the form of a lower output price. The average rate of pass-through is determined, in addition to any market power intermediaries may have, 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 end buyers, intermediaries may choose to give credit to more producers. As these producers move from the spot market to the interlinked transaction, the price they receive falls. While farmers benefit from credit provision, this drives down the average rate of pass-through further than the rate that would obtain if the intermediary were simply an oligopsonist on the spot market. We test empirically the core prediction of the model, that across markets, price and credit pass-through are substitutes. Using an analysis of heterogeneous treatments effects in our experiment, we show that those markets that experience a stronger credit response show a lower rate of price pass-through. The markets in which the credit response is stronger and the price response weaker are precisely those markets in which interlinked transactions were more common in the baseline.

Third, we calibrate our model and show that a model that focuses only on price pass-through will substantially underestimate the change in producer welfare derived from an increase in the buyer price relative to one that accounts for interlinkages. The result is robust to a wide range of parameter values.

Our work supports a view of intermediaries as productive members of the supply chain who undertake value-enhancing investments, as opposed to a view in which they are simply arbitrageurs. In this sense our work is related to that of Rubenstein and Wolinsky (1987) and Antras 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 find another positive role for intermediaries. The authors argue that given the strength of their relationships with clients, they have more information about default risk and can recommend higher quality clients to financial institutions.

Given the context, our work also contributes to the extensive literature on agricultural traders in Africa in particular, initiated by Fafchamps (2004) and continued by 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 importance of business relationships in developing countries by McMillan and Woodruff (1999), Banerjee and Duflo (2000), and more recently Iyer and Schoar (2008) and Macchiavello and Morjaria (2012). These papers focus on characterizing the variation of contractual arrangements between buyers and sellers. Our paper is similar in that we characterize conditions under which relational contracts may emerge, and goes further in that it describes the welfare implications of these contracts.

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. Section 5 tests further implications of the model and presents a calibration and a discussion of its welfare implications. 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 a set of African agricultural markets in which interlinked transactions including credit are common, specifically the cocoa industry of Sierra Leone.[1] 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 other in developing economies discussed in the papers cited in the introduction. In the course of an ongoing business relationship, traders will offer farmers credit, and then allow farmers to repay the loan in cocoa, by accepting from the trader 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 cocoa processing, or could be merely a payment advance that allows the farmer to smooth consumption.

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. 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, we will be able to test a core prediction of our model, that price and credit pass-through are substitutes from the perspective of the trader.

The bonus in our experiment was designed to model fluctuations in the market price received by traders, who themselves sell to wholesalers. 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 countries (for examples in Africa see Fafchamps, et. al. 2005

[1]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.

and Osborne 2005).[2] 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 heterogeneity in pass-through across many different locations. As one moves further down the supply chain, the number of origin locations for cocoa necessarily falls quite quickly.

The cocoa season in Sierra Leone lasts from the beginning of the rainy season in June until February. Our experiment covers the months of September-December of 2011. Prices offered by exporters to wholesalers—who purchase cocoa from our study traders—fluctuate during the season according to the international cocoa price.[3] While this variation might appear attractive for the purposes of our study, it did not prove useful because international price fluctuations affecting wholesalers are infrequent, making it difficult to estimate an effect of pass-through unconfounded by other seasonal variables that may affect supply. This concern motivates an experiment in preference to an observational study. In the following two subsections we discuss respectively the traders and the villages they operate in. Throughout both we discuss the experimental design, the data collected, and summary statistics from these data.

2.1 Traders and the Treatment

We developed our experiment in partnership with five privately owned wholesalers in Sierra Leone's eastern cocoa producing district, three in the town of Segbwema, and one each in the towns Pendembu and Kailahun.[4] These wholesalers collect cocoa in their warehouses, and then sell it on to exporters in the provincial capital of Kenema. Our sample of 80 traders, henceforth

[2]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. The discussion in Gilbert (2009) suggests that Sierra Leone's market is similar to those in Nigeria, Cameroon and Côte d'Ivoire, all of which liberalized during the 1990s, and became similarly fragmented. 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.

[3]Export prices of Sierra Leone's cocoa are set in negotiations between exporters and international buyers, who are generally commodities trading houses. As of 2011, Theobroma, a Dutch firm, bought the majority of the country's cocoa exports.

[4]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 1970s. 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.

study traders, comprise almost the complete set of traders who do business regularly with these wholesalers.[5]

2.1.1 Treatment and Random Assignment

Treatment traders were paid a bonus of 150 Leones per pound of Grade A cocoa. Though this bonus was only a 5.6% share of the price traders received before the treatment, it was a large, approximately 60% increase over average baseline margins. Traders were not told when the treatment price increase would end, though some certainty was given by our research team that it would last for at least a few months.

As emphasized by Atkin and Donaldson (2012), it is important to measure pass-through 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 determinants of quality that are consistent with international standards (see CABISCO, 2002). In order to measure pass-through for given classes of quality, we worked with wholesalers to develop a quality grade 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 the appendix, we discuss in greater detail the construction of the grades, and their relationship to wholesale prices and international standards of cocoa quality.

To improve the statistical power of our experiment, we follow a pairwise randomization strategy (for a review, see 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 matched the traders, we assigned treatment and control within pairs using a random number generator.

[5] In a census of regular business partners of the wholesalers, we counted originally 84 traders. Two were outliers with respect to baseline quantity. They were not matched and thus de facto dropped from the randomization. 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.

2.1.2 Trader Data and Summary Statistics

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 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 reports sales per trader at since the beginning of the season (at that point about half completed) at approximately $4,360.[6] Traders are experienced, with an average of 8.5 years in the industry and 6.5 years selling to the wholesaler. They are also older and have much higher asset ownership than the rural population. Their average age is 38, relative to a rural average of 23 in the 2004 census. 58% have a cement or tile floor (as opposed to dirt or thatch) in their home compared to the 14% rural average in the 2007 National Public Services survey, and 92% own a mobile phone versus 8% in the same survey. 83% have access to a storage facility. The third column of Table 1 shows that treatment and control are balanced on all covariates.

The core data used for the study are data on sales of cocoa to the wholesalers. When traders arrived at the warehouse, our inspectors measured the quality of their shipment and, if the trader had been assigned to the treatment group, he or she was paid a bonus for grade A. Bags were then weighted and quantities recorded. We collected these data for three weeks before treatment assignments were announced. Panel B of Table 1 shows deliveries from this period. These results confirm that treatment and control traders are balanced on the volume of their business: treatment traders sold on average 2,940 pounds and control traders sold 3,180.

In these shipment data, we also collect the price per pound paid to farmers, and the name of the village in which the cocoa was purchased. Questions about which farmers in these villages the bags were purchased from would have been too time consuming to collect, and so farmer prices reported are the average purchase per unit purchase price in a village. Given concerns about measurement error in the farmer per pound price, we also collected information on the total amount paid to farmers for a given bag. Dividing this by weight, we create an alternative measure of the per unit price for use in our results on price pass-through. 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. 3,121 and the average

[6] 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.

price paid for B or C is Le. 3,040.

Finally, in the baseline we asked traders to list each farmer they buy from and all of the villages in which they buy. For each farmer, we asked whether they had given the trader had given the farmer a loan. 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. Importantly, traders have given at least one loan to on average 70% of their clients since the beginning of the season. We repeated this listing exercise one and two months after the treatment began, in the final round asking the amount of the last loan. We will use these data to estimate our treatment effects on credit supply.

2.2 Villages

Study traders reported ever purchasing cocoa in 165 villages. Of these villages, 80 are used in the analysis, because these are the ones for which we have at least one observation of the grade A price after treatment was initiated. Figure 1 presents a map of these villages along with the major towns, and the road network, which is 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 concern about spillover effects between treatment and control. In our regression results, we account for these effects explicitly by including controls for the number of treatment and number of study traders in the village. As shown in figure 1, the villages are relatively close to the large towns; the road distance to the nearest town is 9.6 miles using Dijsktra's minimum distance algorithm along the road network. Importantly, over all study traders, 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. Traders have multiple clients (famers) within each village, on average 6.2, and on average 18.7 clients per village. The population of these villages, calculated using the 2004 census, is substantially greater, at 494 people on average, with a large standard deviation of 753. Though we lack a direct measure of market share sizes, markets appear not to be greatly concentrated. In the baseline, study traders report having on average 5.7 regular competitors in a village. 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 is statistically insignificant at standard levels.

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, as would be predicted by a simple model of perfectly competitive traders. 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 (2006).

3.1 Price Pass-Through

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

$$y_{kipvt} = \alpha_{ip} + \tau_t + \mathbf{X}_i'\boldsymbol{\beta_x} + \mathbf{W}_v'\boldsymbol{\beta_w} + \theta^p(\text{Bonus}_i) + \epsilon_{kiptv} \quad (1)$$

The term α_{ip} 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 generated by the international market. The vector $\mathbf{X}_i'$, used in some specifications, includes the trader-level covariates of age, years working with wholesaler and dummies for ownership of a mobile phone and a concrete floor. The latter term is a useful proxy for wealth in our context. The vector $\mathbf{W}_v'$ includes the village-level covariates of minimum road distance to nearest town, number of study traders, number of other treatment traders, and baseline share of farmers having ever received credit from a study trader. Bonus_i is a dummy equal to one if trader i is assigned to treatment, and so θ is the average treatment effect. The term ϵ_{iptv} is an error. Pairwise randomization motivates the assumption that $E[\epsilon_{kiptv}|\text{Bonus}_i, \alpha_{ip}, \tau_t, \mathbf{X}_i', \mathbf{W}_v'] = 0$.

The term θ^p is the coefficient of interest. We will pick y_{kipvt} to be the level of prices so 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 of the bonus. Table 3 presents estimates of θ^p. In a basic specification in column 1, 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.

Given that some villages contain both treatment and control traders, we are concerned about spillovers between groups. It may be that Bertrand competition between treatment and control traders drives up the price offered by control traders, so that there is no difference between the prices offered by both groups. We test for this by adding trader and village level controls, which include the number of treatment and control traders in column 2. This is a specification similar to the one developed to test for externalities by Kremer and Miguel (2004). In this column, the estimate of θ^p can be interpreted as the effect of treatment in a market with no other study traders and no treatment traders. It is statistically indistinguishable from the estimate in column 1, with $\theta^p = -4.4$ (s.e. = 11.1). Column 3 presents the same regression using as our outcome an alternative measure of price taken by dividing a trader's total expenditure by its weight, again we reject perfect pass-through and cannot reject that pass-through is equal to zero. This provides reassurance that our price results are not driven by measurement error in prices. In columns 4 and 5, we also present results for grade B and C cocoa. For grade B, in column 4, pass-through is positive and statistically significant at 1 percent, with $\theta^p = 49.41$ (s.e. = 11.76). At first pass this is surprising. How could pass-through for grade A be zero, and pass-through for grade B be so much higher? We argue that this is consistent with 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. That in column 5 we see pass-through is again reduced for grade C, which is much less likely to be mistaken for grade A, confirms this intuition.

3.2 Transport Costs

In a perfectly competitive model of price pass-through, the difference in price between two locations that trade will equal the marginal cost of transport. Thus, our lack of pass-through could be explained by the fact that marginal costs of transport are increasing rapidly among treatment traders, who now bring more cocoa per shipment. Table 4 presents estimates of equation (1), with outcomes related to cost in the place of y_{ipvt}, using all grades of cocoa shipped. Columns 1 and 2 show that the weight per shipment—scale—is increasing significantly by the treatment. In the preferred specification with village and trader controls we have that treatment traders increase their shipment volume by 8.20 (s.e. = 2.37). In columns 3 and 4, we see that unit costs reported by the trader are also falling. When shipments arrived, we recorded the total cost of transporting of that shipment to the wholesaler. Unit costs are obtained by dividing this by weight. In the preferred specification with village and trader controls we have that the treatment effect is -11.38 Leones (s.e. = 2.38). This implies that in addition to the bonus of 150 Leones per unit, traders also received a gain in the form of 11 Leones lower transport costs per pound shipped. Finally column 5, which amounts 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, shows that this cost result is being driven by a change in transport technology. As shown in Figure 2, which plots unit cost by transport technology, trucks have consistently lower per unit costs. It is our understanding from conversations with traders that trucks are easier to hire if one has a larger total shipment size, as the truck driver himself must amortize the fixed cost of driving to the pick up location. These results show that the lack of pass-through cannot be explained by increasing marginal costs. They also confirm those of Fafchamps et. al. (2005) for Africa, who find evidence of increasing returns to scale in transport in Malawi and Madagascar, though not in Benin.

3.3 Credit

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

$$y_{fipv} = \alpha_{ip} + \mathbf{X_i'}\boldsymbol{\beta_x} + \mathbf{W_v'}\boldsymbol{\beta_w} + \theta^{\mathbf{c}}(\text{Bonus}_{\mathbf{i}}) + \nu_{\mathbf{fipv}} \quad (2)$$

where y_{fipv} is a credit provision indicator related to farmer f in village v was given credit by trader i of pair p. The term θ^c is the treatment effect estimator, and ν_{fipv} is an error term. All other terms are as in (1), except that we have removed the week fixed effect, since we only observe the outcome variable in one cross section. 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). The effect on credit is substantial. In columns 1 and 2, the outcome is a dummy equalling one if credit was provided to a farmer in the last month, making this regression equivalent to a linear probability model. In column 2, the preferred specification with trader and village controls, the bonus raises the likelihood of credit provision to a given farmer by $\theta^c = 12$ (s.e. = 3) percentage points, off the control group mean of 12%—a doubling of the likelihood of providing credit. In columns 3 and 4, we see this 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. Those that did not give any were set equal to zero. In the preferred specification in column 4, we see that traders are more than doubling their credit outlay, with $\theta^c =$ Le. $10,107$ (s.e. = 4,759), off a control group mean of Le. 18,908.

4 A Model of Pass-though in Interlinked Transactions

In this section, we develop a simple model of interlinked transactions between intermediaries and producers, who we will call traders and farmers to match the context of our experiment. We derive the equilibrium output prices paid to farmers and the level of credit provision. We show how these variables respond to an increase in the wholesale price—the price at which traders resell their purchases—and conclude by studying the average welfare effects of such a change on farmer welfare in this model. We contrast them with those derived from a benchmark model that does not account for interlinkages.

4.1 Environment

The economy is composed of M isolated markets. Each market m is populated by I_m farmers and J_m traders. Farmers i in market m are each endowed with an amount of land that produces a fixed amount of output, q_{im}, which we will write as q_i to reduce notation.[7] The quantity q_i varies across farmers and production costs are zero. The profit of farmer i is $\pi_i = q_i \cdot p_i$, where p_i is the farmgate price received. The profit of trader j purchasing from farmer i is $\pi_{jim} = q_i \cdot (w - p_i)$, where w is the wholesale price received by the trader. Traders are homogenous.

Interactions between the two agents can occur under two alternative contracts. In *spot markets*, the trader and farmer transact only at harvest time. This contract can be viewed as the benchmark model, with no interlinkages. In *interlinked transactions* (ILT), a trader provides credit before harvest and then purchases output from the farmer at harvest at a pre-determined price, unless the farmer chooses to default. The benefit of this contract to the trader is greater volume—the contract "locks in" the farmer's supply, and ensures it is not sold to another trader on the spot market.[8] We discuss next each agent's payoff structure under the two types of contracts.

[7] The assumption of perfectly inelastic supply is reasonable in a context such as agriculture, where production decisions take place months before output prices are realized.

[8] In a variant on this, the credit can be productive, and allow the farmer to produce more physical quantity.

4.1.1 Spot Markets

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

$$p^S_m = \frac{w_m}{\mu}, \quad \mu \geq 1 \tag{3}$$

The mark down is a reduced form capturing both trading costs proportional to value and any market power the trader may have. The utility of farmer i farmer transacting on the spot market is:

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

On the spot market 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:

$$v^S_{jim} = \frac{1}{J_m}(w_m - p^S_m) q_i = \frac{1}{J_m}\frac{\mu - 1}{\mu} w_m q_i \tag{5}$$

4.1.2 Interlinked Transactions

In interlinked transactions, a trader provides credit before harvest, and subsequently purchases output at a pre-determined price. We assume that traders and farmers are randomly matched, and since traders are homogeneous, if the first one decides not to offer credit, none of the others will do so. This simplifying assumption allows us to only consider the credit provision choice of the one trader matched 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.[9] The farmer's marginal utility from consuming the credit c is $c_F = \lambda \cdot c$, with $\lambda \geq 1$. This is a reduced form for the increased utility of the farmer from consumption smoothing, which is assumed to be weakly larger than the trader's utility cost of disbursing the loan. One way to think about this is that the farmer experiences a higher marginal utility per unit of income relative to the trader in the pre-harvest season.[10]

After receiving credit, the farmer decides whether to stick to the terms of the contract or to undertake a strategic default. If the farmer respects the contract, he receives a farmer-specific

[9] This assumption simplifies our exposition. Endogenizing the amount of credit provided per bag does not alter our main predictions.

[10] An alternative model in which credit increases either the quality or the quantity of output delivers very similar predictions to the one derived here. In our empirical setting, however, we believe that the main role of credit, though certainly not the only one, is to facilitate consumption smoothing.

contract price p^C_{im}. We describe how this price is determined in equilibrium in section 4.2. When he does not default, the utility of farmer i under ILT is

$$u^{CN}_{im} = (p^C_{im} + c_F)q_i \tag{6}$$

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

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

Note here that the trader's utility no longer includes the term $1/J_m$, since under the contract he is now certain to get the farmer's output.

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. He then sells $(1-\gamma_{im})q_i$ on the spot market. The parameter γ_{im} is reduced form measure of contracting institutions capturing market characteristics that could shape the cost of default, including trader monitoring costs, proximity to law enforcement, and social norms specific to farmer i. In the strategic default scenario, the utility of farmer i in the ILT contract is

$$u^{CD}_{im} = \left(p^S_m(1-\gamma_{im}) + c_F\right)q_i = \left(\frac{w_m}{\mu}(1-\gamma_{im}) + c_F\right)q_i, \tag{8}$$

while the utility of trader j is

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

4.2 The Equilibrium Contract

In this subsection, we describe the conditions under which farmers and traders will opt to transact on the spot market or in an ILT, and the conditions under which ILT will persist as a Nash equilibrium. 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^C_{im}. If the trader does not offer credit they transact on the spot market. If the trader does offer credit, they proceed 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. In the third stage, the farmer decides not to default if

$$u^{CN}_{im} \geq u^{CD}_{im} \Rightarrow p^C_{im} \geq \frac{w_m}{\mu}(1-\gamma_{im}). \tag{10}$$

This is the farmer's incentive compatibility constraint. In order not to induce default, the trader must offer a large enough contract price to satisfy it.

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

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

which highlights the fact that the decision to participate in credit depends on the proposed contract price, p_{im}^{C}. In the first stage, the trader decides whether to offer credit and, if so, the contract price to offer. Here for simplicity we consider only the equilibrium in which he chooses a contract price such that the farmer's incentive compatibility constraint (10) binds with equality, and the farmer receives no extra rent from the credit relation.

Thus, the trader sets price

$$p_{im}^{C*} = \frac{w_m}{\mu}(1 - \gamma_i m), \tag{12}$$

which is decreasing in the quality of contracting institutions. Given this optimal price, he decides to offer credit to farmer i if

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

We can now establish Proposition 1.

Proposition 1 *Interlinked transaction contracts arise as the equilibrium contractual form if the inequalities in equations 13 and 11 hold. The equilibrium 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 production, q_i, while contract institutions are vary only at the market level, denoted γ_m, and μ is constant across markets. In this case, farmer i and trader j in market m enter an ILT arrangement if: i) $q_i \geq q_m^* \equiv \frac{fJ_m\mu}{w_m(J-1)(\mu-1)+\gamma w_m - cJ_m\mu}$; ii) $\gamma_{Lm} \leq \gamma_m \leq \gamma_{Hm}$, where $\gamma_{Lm} \equiv \frac{c\mu}{w_m} - \frac{(J_m-1)(\mu-1)}{J}$ and $\gamma_{Hm} \equiv \frac{c_F}{\mu}$. Intuitively, traders provide credit only to those farmers whose quantities are large enough that the increase in revenues for the traders to provide credit more than offset the fixed cost of credit provision f. In addition, observe that, under the parameter restriction on γ_m imposed by (ii) above, the minimum production volume a farmer needs to produce to access credit is decreasing in J_m and γ_m, and increasing in f. Intuitively, credit provision increases when the relative benefit for the trader from interlinked transactions increases. This occurs when: a) the number of competitors increases (and thus the expected profit from spot market interactions decreases); b) the quality of contracting institutions increases (and thus the contract price the trader has to offer to induce no-default falls); c) the fixed cost from credit provision decreases. The equilibrium contractual form determines the price each farmer faces. Farmers on the spot market sell at $p_i = p_m^S$. Farmers in an ILT arrangement sell at $p_i = p_{im}^{C*}$

4.3 Comparative Statics

In this section, we study the impact of an increase in the wholesale price the trader faces. We restrict the analysis to the case in which some farmers find it optimal to default and thus do not receive ILT in equilibrium; contracting institutions are not so perfect that at least some farmers are always better off by accepting a credit provision offer and defaulting than by rejecting the offer. This assumption is summarized by

Parameter Restriction 1 $\gamma < \frac{c_F \mu}{w_m}$

Under this restriction, $v_{jim}^{CN} - v_{jim}^{S}$ is easily shown to be increasing in w_m, which leads to the following result.

Proposition 2 *For a pair i j, if the interlinked transaction contract is the equilibrium at w_m', it will always be an equilibrium at $w_m'' > w_m'$. Conversely, if spot market contract is the equilibrium at w_m', it needs not be an equilibrium at $w_m'' > w_m'$.*

In other words, there exist sets of parameters such that an increase in the wholesale price leads to farmers switching from the spot market to ILT. We consider again the case where q_i is the only parameter varying across farmers in a given market. Proposition 2 stems from the fact that the threshold level of production required to supply credit in a given village, q_m^*, decreases in response to an increase in w_m. As w_m increases, a greater share of farmers switch to ILT. Figure 3 shows the increase in credit status in response to a discrete increase in the wholesale price, as a function of γ and q.

We now consider how p_i changes in response to change in w_m from w_m^0 to $w_m = w_m^0 + \Delta$, where Δ is some constant. Observe that the change depends on whether the farmers are on the spot market, in an ILT, or whether they switch into ILT in response to the change in w_m. First, farmers who remain on the spot market experience an increase in their price, p_m^S, of $\frac{\Delta}{\mu}$. This is pass-through, conditional on the markdown, as in a benchmark model that does not allow for interlinked transactions. Second, farmers who were in ILT contracts both before and after the change in w_m experience an increase in their contract price, p_{im}^C, of $\frac{\Delta(1-\gamma_m)}{\mu}$. Third, farmers who enter an ILT contract in response to the increase in w_m face the following change in price: $\frac{\Delta(1-\gamma_m)-\gamma_m w_m^0}{\mu}$. The last result shows that farmers switching into ILT in response to the change experience a decrease in price, since they switch from the spot price to the contract. They are however still better off, because they are now getting credit.

Figure 4 summarizes the price response for different combinations of γ and q. The graph points at the main result from the theory. The credit and pricing pass-through in response to a change in the wholesale prices are substitutes. Those pairs (γ, q) that switch into ILT are exactly the ones experiencing a decrease in output prices. For the remaining pairs, who stay in the same contract form, the price goes up. The average effects of a price change on price and credit pass-through will be a weighted average of these effects, and depend on the measure of farmers switching contracts.

4.4 Welfare Analysis under Interlinked Transactions

In this section we use our model to study the effect of a change in wholesale prices on farmer welfare and compare it those derived from a benchmark model without interlinked transactions. As above we simplify the exposition by assuming contract institutions are fixed across farmers at the market level, γ_m. Production q_{im} is still allowed to vary across farmers within a given market. We assume q_{im} is distributed with cumulative distribution function $G(q_{im})$ defined over the support $[q_{Lm}, q_{Hm}]$. Thus there exists a $q_m^*(w_m)$ that is the production volume threshold above which farmers enter ILT contracts. The insights of the analysis are similar when we relax this assumption of a constant γ_m in the market. Below, we consider a single market and simplify notation by omitting the subscript m.

The average farmer welfare in a market is equal to:

$$W^{ILT} = \int_{q_L}^{q^*} q\frac{w}{\mu}g(q)dq + \int_{q^*}^{q_H} q\left(\frac{(1-\gamma)w}{\mu} + c_F\right)g(q)dq, \tag{14}$$

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 effects of an increase in the wholesale price w, we apply Leibniz's rule to obtain

$$\frac{dW^{ILT}}{dw} = G(q^*)E[q|q<q^*]\frac{1}{\mu} + (1-G(q^*))E[q|q \geq q^*]\frac{(1-\gamma)}{\mu} - (c_F - \gamma\frac{w}{\mu})q^*g(q^*)\frac{dq^*}{dw} \tag{15}$$

Intuitively, the change in welfare is the sum of three terms: i) the average change in welfare for farmers on the spot market, weighted by the share of farmers on the spot market; ii) the average change in welfare for farmers on ILT contracts, weighted by the share of farmers in ILT; iii) 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 whole term is positive under the Parameter Restriction 1.

We compare these welfare results with those of a benchmark model, where farmers only transact on the spot market. In this benchmark case average welfare is

$$W^S = \int_{q_L}^{q_H} q\frac{w}{\mu}g(q)dq, \tag{16}$$

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

$$\frac{dW^S}{dw} = E[q]\frac{1}{\mu} \tag{17}$$

Equation (17) shows that, in the absence of credit provision, price pass through is the key variable that shapes predicted welfare changes. This simple result derives from the assumption of perfectly inelastic supply at the farmer level, and our constant markdown, μ. In a richer model, for instance one with Cournot intermediaries and a village supply curve, the mark down would vary with quantity transacted. Our constant markdown assumption is useful on the one hand, as it illustrates clearly the key insight of the paper. On the other, a more general model would add additional predictions about how the welfare response to an increase in the wholesale price varies with quantity.

5 Model Testing and Calibration

5.1 The Substitutability of Price and Credit Pass-through

The core testable prediction of our model is that price and credit pass-through are substitutes across markets. In this section we provide evidence on this substitutability using data from the 80 markets in our experiment. A key result will be that while price pass-through is positive in some markets, it is low and even negative in others. This heterogeneity is driven by the baseline intensity with which interlinked transactions are used in these markets. This finding emphasizes the core result of our paper, that price-pass-through is diminished in the presence of interlinked transactions. An increase in the wholesale price leads to a reduction in farmer prices for those farmers who switch into interlinked transactions as a result of the increase. We conclude this section with a welfare calibration of our model, showing that the effects of ignoring the margin of credit pass-through can be substantial for welfare analysis.

As a preliminary step, we document first that several correlations from the baseline data are consistent with the predictions of the model. Table 6 presents these results. Each column shows a regression of the village outcome on the proxies listed in the rows and a constant. These indicators come from the pre-treatment period, when our inspectors were collecting data on the quantity, prices and quality of cocoa delivered to wholesalers, but treatments had not been assigned. Our model predicts a negative cross-sectional correlation between the level of prices and the supply of credit at the village level. This is confirmed in columns 1 and 2 of Table 7. Column 2 is the preferred specification as it includes other correlates which may affect price, such as minimum road distance to the nearest town and the number of study traders, a proxy for market size. As shown in column 2, moving from zero credit share to full credit share decreases the price paid in the cross section by 4.2 percent (s.e. = 2.3). In column 3, we present a regression where the outcome variable is the village-level share of farmers receiving credit from study traders. This outcome is positively correlated with the total quantity supplied to traders, which is calculated as total quantity supplied in baseline, divided by the number of study traders. This confirms the model's insight that traders are more likely to extend credit to villages from which they can get higher volumes of cocoa. In addition, village-level credit share is also positively (and significantly) correlated with the number of traders in the economy, confirming another prediction of our model that markets with more traders, and thus a greater threat of loosing output to a competitor, are related to more intensive use of interlinked transactions.

We now test the prediction that price and credit pass-through are substitutes across markets by studying across-village heterogeneous treatment effects of the experiment. We modify equations (1) and (2) respectively to allow for heterogeneous treatment effects across villages by specifying the two regression equations

$$y_{kipvt} = \alpha_{ip} + \tau_t + \mathbf{X}_i'\boldsymbol{\beta_x} + \mathbf{W}_v'\boldsymbol{\beta_w} + (\text{Bonus}_i \times \mathbf{W}_v')\boldsymbol{\theta_w^P} + \theta^P(\text{Bonus}_i) + \epsilon_{kiptv} \tag{18}$$

$$y_{fipv} = \alpha_{ip} + \mathbf{X_i'}\boldsymbol{\beta_x} + \mathbf{W_v'}\boldsymbol{\beta_w} + (\text{Bonus}_\mathbf{i} \times \mathbf{W_v'})\boldsymbol{\theta_w^C} + \theta^{\mathbf{C}}(\text{Bonus}_\mathbf{i}) + \nu_{\mathbf{fipv}} \tag{19}$$

where $\mathbf{W}_v'$ is some vector of village covariates as before. For any village v then we have an estimator for the pass-through in that village given by

$$\hat{\rho^s} = \mathbf{W}_v'\boldsymbol{\theta_w^s} + \theta^s \tag{20}$$

where $s \in \{P, C\}$, price or credit. Our model predicts that $\hat{P} = Corr(\hat{\rho}^P, \hat{\rho}^C) < 0$ across villages with different market size, the level of competition, and the ease of enforcing contracts. The challenge then is to pick a sufficiently rich vector $\mathbf{W}_v'$ that will capture this heterogeneity. There is a trade off in this exercise in that adding too many variables may introduce too much noise, whereas having to few may produce insufficient variation across villages to generate an effect.

The most natural starting point for an element of $\mathbf{W}_v'$ is a baseline measure of credit supply at the village level, which proxies directly for the prevalence of interlinked transactions in a given market. As discussed above, we are able to generate such a measure from our baseline survey of traders. For all the farmers listed by study traders in the baseline, we calculate the within-village share of farmers that has been given credit by a study trader since March, shortly before the cocoa season begins. As shown in Table 2, the mean of this variable across study villages is 65%, with a standard deviation of 29 percentage points. To gain more variation we will add to $\mathbf{W}'_v$ the minimum road distance to the nearest town, a proxy for ease of enforcement of contracts, as well as factors that may affect per unit transport costs, and the number of study traders in the village, a proxy for market size.

We proceed to estimate to estimate (18) and (19) using seven different specifications of $\mathbf{W}'_v$, and to report $\hat{P}_r = Corr(\hat{\rho}_r^P, \hat{\rho}_r^C)$ for each specification r. In each specification we weight observations by the inverse number of observations per village to make the specifications comparable—recall that in the case of price observations are shipments and in the case of credit they are farmers. The regression coefficients $\boldsymbol{\theta_w^s}$ and θ^s for each model are presented in Table 7, and the estimates of $\hat{P}_r$ are presented in Table 8. Standard errors for each $\hat{P}_r$ are constructed by resampling with replacement both the price and credit sample 500 times, each time reestimating (18) and (19). For each iteration, we estimate $\hat{\rho_r^s}$ for each s, and hold the correlation in memory. The standard error is the standard deviation of these correlations, and the test statistic is the $\hat{P}_r$ divided by its standard error.

The models, or different specifications of $\mathbf{W}'_v$, are as follows. Model A includes only baseline credit share. In columns 1 and 2 of Table 7 we see that the interaction terms have the opposite sign, as expected. In markets with higher baseline credit share, price pass-through is lower, though not significantly so, and credit pass-through is higher, and significant at 1 percent. Since there is only one variable in this model, the correlation coefficient presented in Table 8 is necessarily -1.0. Model B is our baseline linear model, including interactions terms with baseline credit share, the number of study traders, the number of treatment traders and minimum distance to the nearest town. We include the number of study traders to assuage concerns about spillover effects. Again, the signs on baseline credit share are the opposite sign, as expected. The correlation coefficient across villages generated by this model is -0.88. With a standard error of 0.24, this is significant at 1%. A scatter plot and best fit line indicating the relation between the two predicted treatment effects is presented in Figure 5. The negative relationship is clear. Model C includes the same covariates, but includes quadratic and cubic terms for each to allow for non-linearity in the treatment effects as they vary with the covariates. In this model, the correlation coefficient is smaller, at -0.44, but still significant at 6 percent with a standard error of 0.23. Adding the quadratic and cubic terms increases the variance of the overall predicted effects, but does not change the overall pattern.

The rest of the models drop covariates other than baseline credit share to show the robustness of the relationship. Model D includes only baseline credit share and minimum road distance, and model E includes these variables with quadratic and cubic terms. Again the coefficients remain negative, at -0.99 (s.e. = 0.33) and -0.68 (0.23) respectively. Model F includes only baseline credit share, number of study traders and number of study traders, and model G includes these in addition to quadratic and cubic terms as before. Here the relationship is negative, at -0.78 (s.e. = 0.29) and -0.25 (s.e. = 0.25) respectively in each model, though it is not significant at standard levels in model G. The best fit lines for these models are summarized in Figure 7. In sum, the results show a robust and strong negative relationship between credit and price pass-through across markets.

5.2 Calibration and Welfare Analysis

Our results emphasize that a focus only on prices may obscure the total value passed through to farmers. A calibration of our model provides an illustration of the extent to which not accounting for interlinked credit transactions may underestimate the effect of a change in the wholesale price of output on the average farmer's welfare, and under which parameter values the bias will be most severe. These calculations rely heavily on the model, which makes several simplifying functional form assumptions, and the precise magnitudes of our results should be interpreted with caution. Nevertheless, we believe that this exercise is useful, and helps illustrate the point that the inferences one draws about welfare from low pass-through in a market with interlinked transactions can be substantially different from those one would draw using a standard pass-through model.

We analyze the change in welfare with respect to a marginal increase in the wholesale price in a benchmark model without interlinkages and in our model. In the benchmark model, the change is given by (17). Since farmers receive $1/\mu$ of the wholesale price, the markdown is equal their welfare change per unit sold. We multiply by the average farm size to obtain an estimate of the change in average welfare in the economy.

In our model of interlinked transactions, the effect on welfare of a price is a weighted average of three terms, the effect on those who still receive no credit, those who still receive credit after the change and those who switch into the interlinked transaction. This result is summarized by (15), restated here:

$$\frac{dW^{ILT}}{dw} = G(q^*)E[q|q < q^*]\frac{1}{\mu} + (1 - G(q^*))E[q|q \geq q^*]\frac{(1-\gamma)}{\mu} - (c_F - \gamma\frac{w}{\mu})q^*g(q^*)\frac{dq^*}{dw}$$

In our calibration we will estimate all terms except μ and γ from the data, and then compare (17) and (15) for different values of the two parameters. It remains then to obtain values for $G(q*)$, $E[q|q < q*]$, $E[q|q > q*]$, c_F, w, $q*$, and $g(q*)\frac{dq^*}{dw}$.

We begin with c_F, the utility gain to the farmer from the credit relation per unit sold. A natural starting point is the cash value of the average loan given to farmers, divided by the average quantity sold by a farmer. Our data on loan size come from the endline survey, asked in late December, 2011. Traders were asked if they had given a loan in the last thirty days, and if so, how much. The average loan size was Le. 177,297 (s.d. = 143,594), approximately 45 US dollars. To arrive at a per unit quantity, we must assume a period over which the loan was amortized. To be conservative, we will choose two months. Choosing a shorter period would make our estimates of the marginal utility from a loan higher. To calculate per farmer quantity sold during that period, we calculate total quantity of grade A purchased by all traders in each village in the month before the question was asked. We then divide this by the number of suppliers in the village, and take the average, arriving at 96 pounds. Assuming that the trader, when giving the loan expected to receive this flow for four months, the implicit per unit credit outlay is 923 Leones. We assume that λ, the marginal utility for the farmer of a one-dollar credit provision, is 1.3, so we have $c_F = 1,201$. Current prices at this time are Le. 2,666 per pound so we take that to equal W_0.

Now we must estimate the share of farmers in the credit relation, and those who are not. Since the data on credit provision were collected referencing the last month, we will use this same time frame to estimate the share of farmers currently in an interlinked transaction. This is just then the control group's share of people who have received credit in the last month, 12%. We use this value for $G(q*)$. To estimate the expected farmer loan size for traders in and out of the credit relation, we return to baseline data on quantities sold by each village to all of our study traders, so that our estimates of quantities are not influenced by the treatment. We use the baseline share of farmers who have received credit in that village since the beginning of the season as our proxy for the level of the credit in that village. The median value of this variable across villages is 63%. We code villages above this median as being in the credit relation, and those below this median as being outside of it, and then calculate average baseline quantity sold during the 4 pre-treatment weeks of the experiment per farmer in the village for the two groups. From this we arrive at $E[q|q < q*] = 36$ and $E[q|q > q*] = 95$. For the value of $q*$, we simply take expected per farmer quantity for the median village with respect to the credit share, getting $q* = 67$.

Finally, we require a term for $g(q*)\frac{\partial q*}{\partial W}$, the change in the threshold value of $q*$ times its density. This we can estimate from our treatment effects. If each unit of q represents a farmer, a decrease in $q*$ is just the negative of the change in the share of people getting credit. If we assume this term is constant, it is just equal to the negative of the slope of our treatment effect on credit with respect to the increase the bonus, or $-0.12/150 = -0.0008$. Finally, to estimate the change in the standard model, we just require expected quantity per farmer, which in the baseline equals 66 pounds.

Figure 7 summarizes the results of our calibration of the welfare impact of the experiment with and without accounting for the credit margin. Specifically, the figure shows the ratio between the average welfare changes estimated using the interlinked transaction model (15) and using the benchmark framework (17), for a range of values of γ and μ, and the calibrated values discussed above. The ratio is larger than in most cases. Intuitively: i) it is increasing in μ, since a higher markdown reduces the price pass-through, which is the sole driver of welfare change in the benchmark model; ii) it is decreasing in γ, since better contract enforcement institutions increase the amount of rent traders can extract from farmers when they provide them with credit. In conclusion, the exercise shows that neglecting the role of interlinkages can substantially affect the estimation of the welfare consequences of a change in wholesale prices.

6 Concluding Remarks

The theory and evidence presented here show that in the presence of interlinked transactions low price pass-through may obscure other channels through which value is passed from end buyers to producers. Price pass-through and credit pass-through are shown to be substitutes across markets in an agricultural market in sub-Saharan Africa that has similarities to markets in other developing economies. This is shown to have substantial implications for the relationship between farmer welfare and pass-through. Indeed, in our context, low price pass-through need not be evidence of intermediaries' market power, but rather simply that interlinked transactions are common, and that rural capital markets are functioning smoothly, to the benefit of farmers. Our work complements existing work on the welfare implications of pass-through by extending their framework to cover a broad class of transactions common in developing economies. More broadly, interlinkages play role in a wide range of transactions; for instance, trade credit plays a key role in international trade contracts (Antràs and Foley, 2011). Our argument that one needs to assess the multiple margins through which value passes-through the value chain is thus a general one.

While our empirical work studies pass-through at the level of the intermediary buying from a producers, the issues described here naturally extend to intermediaries at different links in the supply chain. We believe the question of how interlinkages affect the transmission of price signals through entire supply chains, for instance from the world market to the cocoa farmer, is an exciting one that features prominently in our agenda for future research.

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 Sonii (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 9 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, members of our research team 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.

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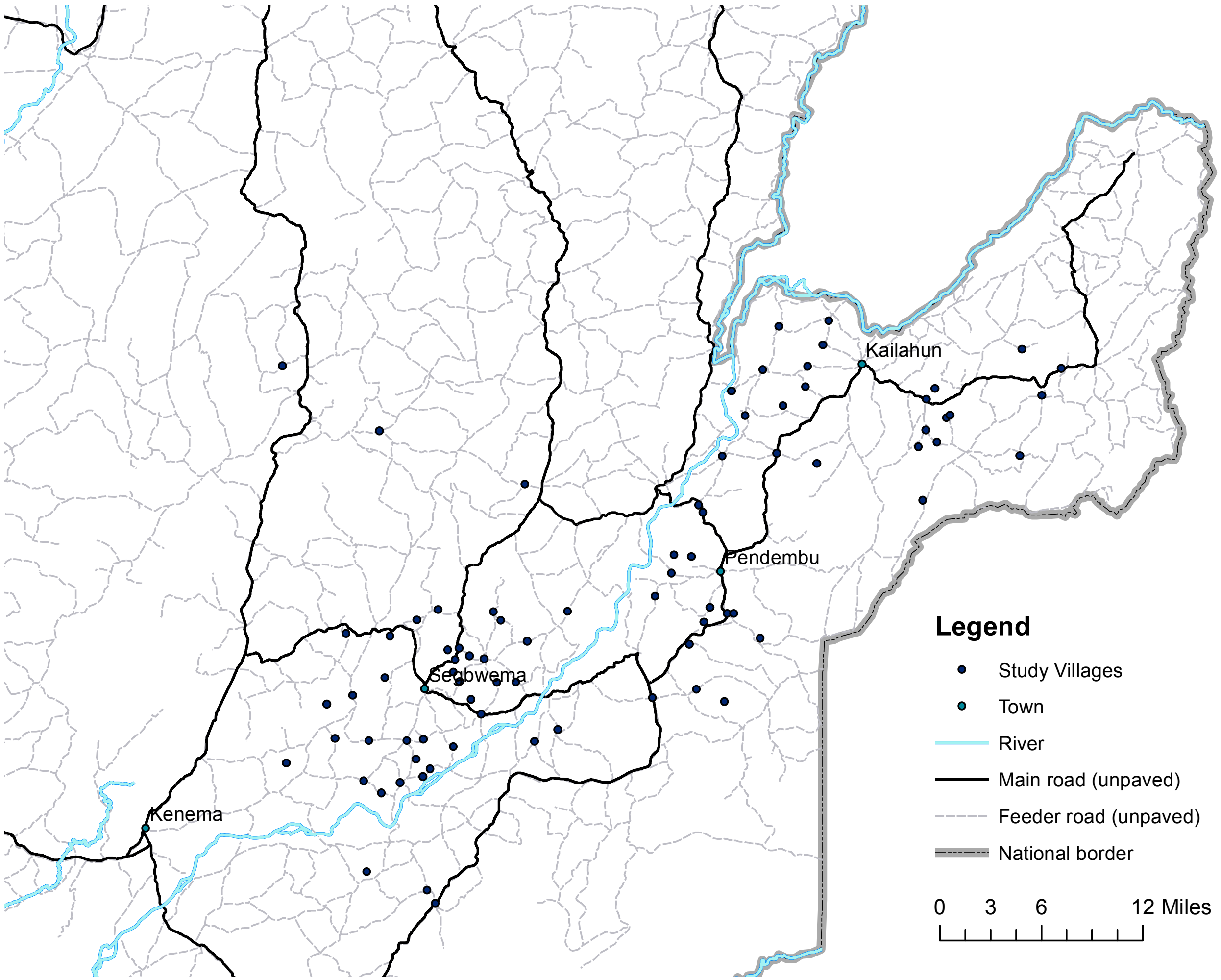


Figure 1: Map of study villages

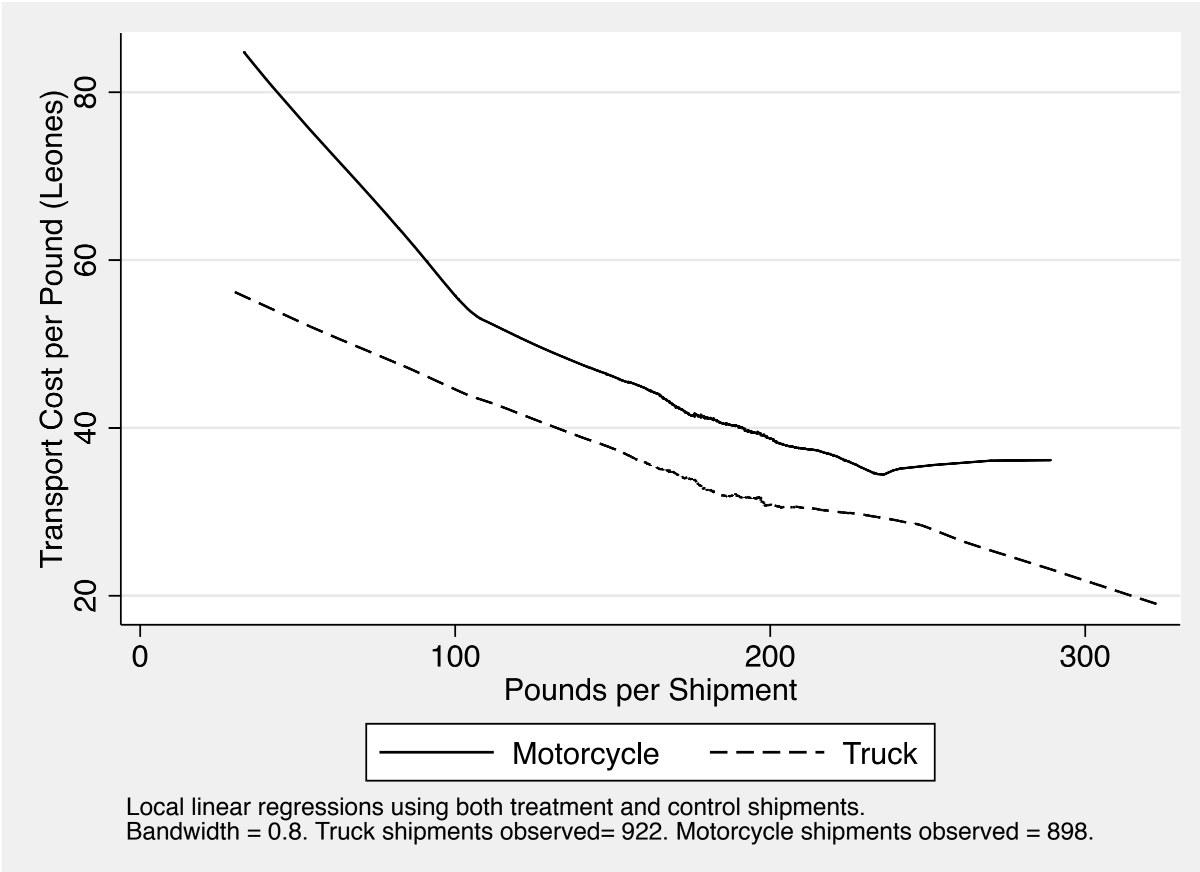


Figure 2: Declining unit costs by transport technology

Figure 3: The impact of a change the wholesale price on credit provision. Red indicates negative values, blue positive.

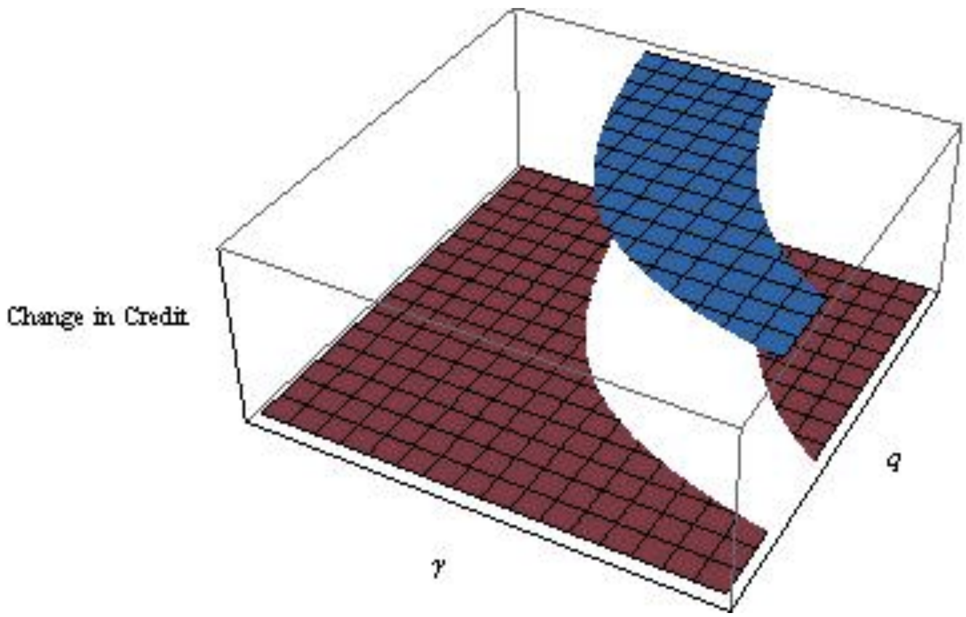
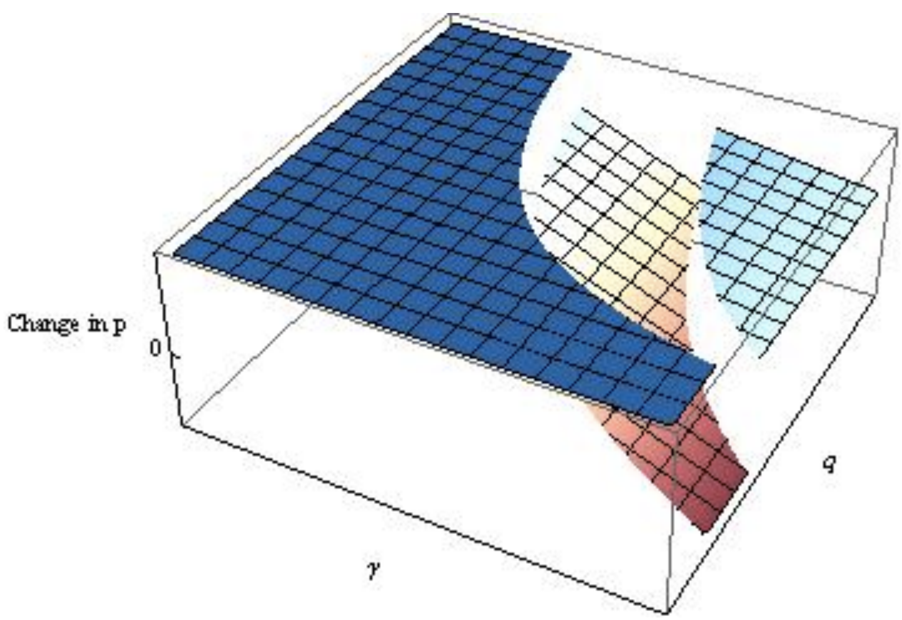


Figure 4: The impact of a change in the wholesale price on farmer prices. Red indicates negative values, blue positive.



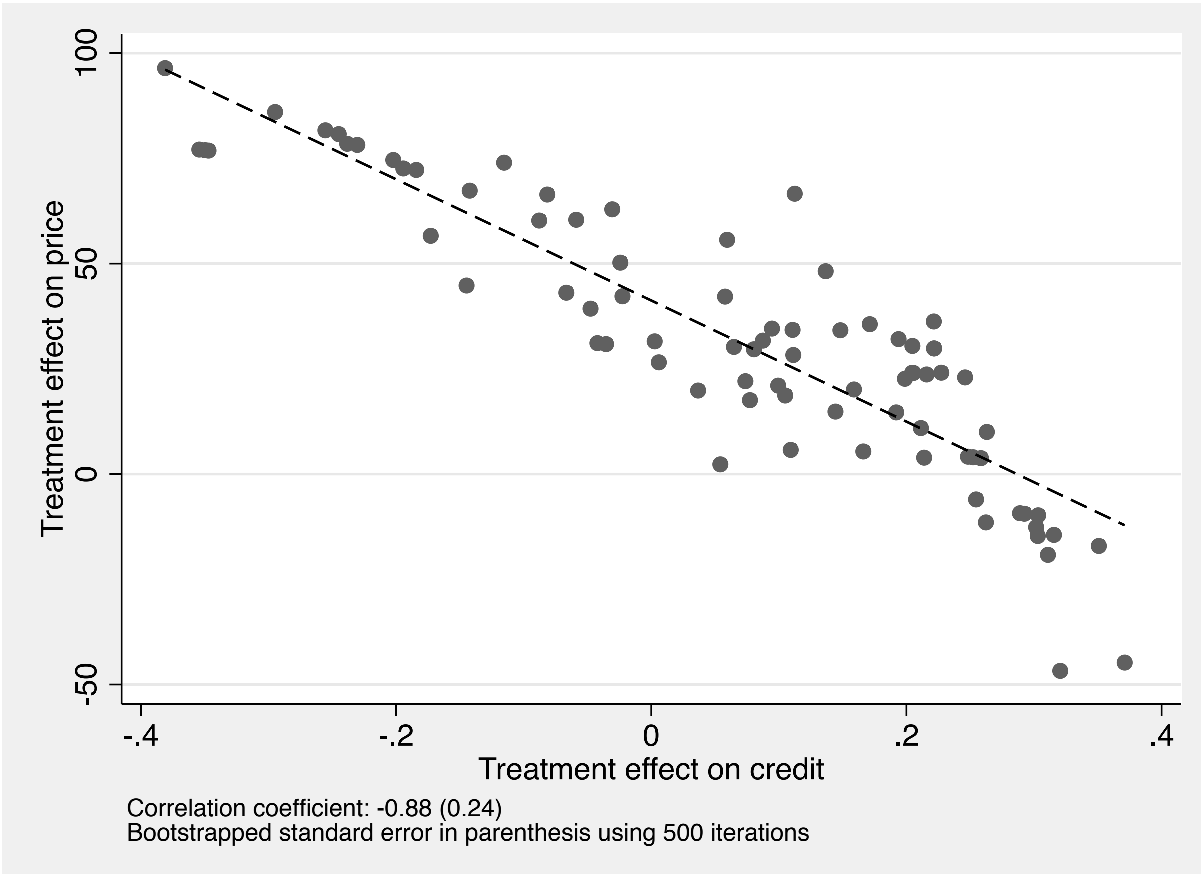


Figure 5: Substitutability, correlation of predicted treatment effects in baseline linear model (Model B).

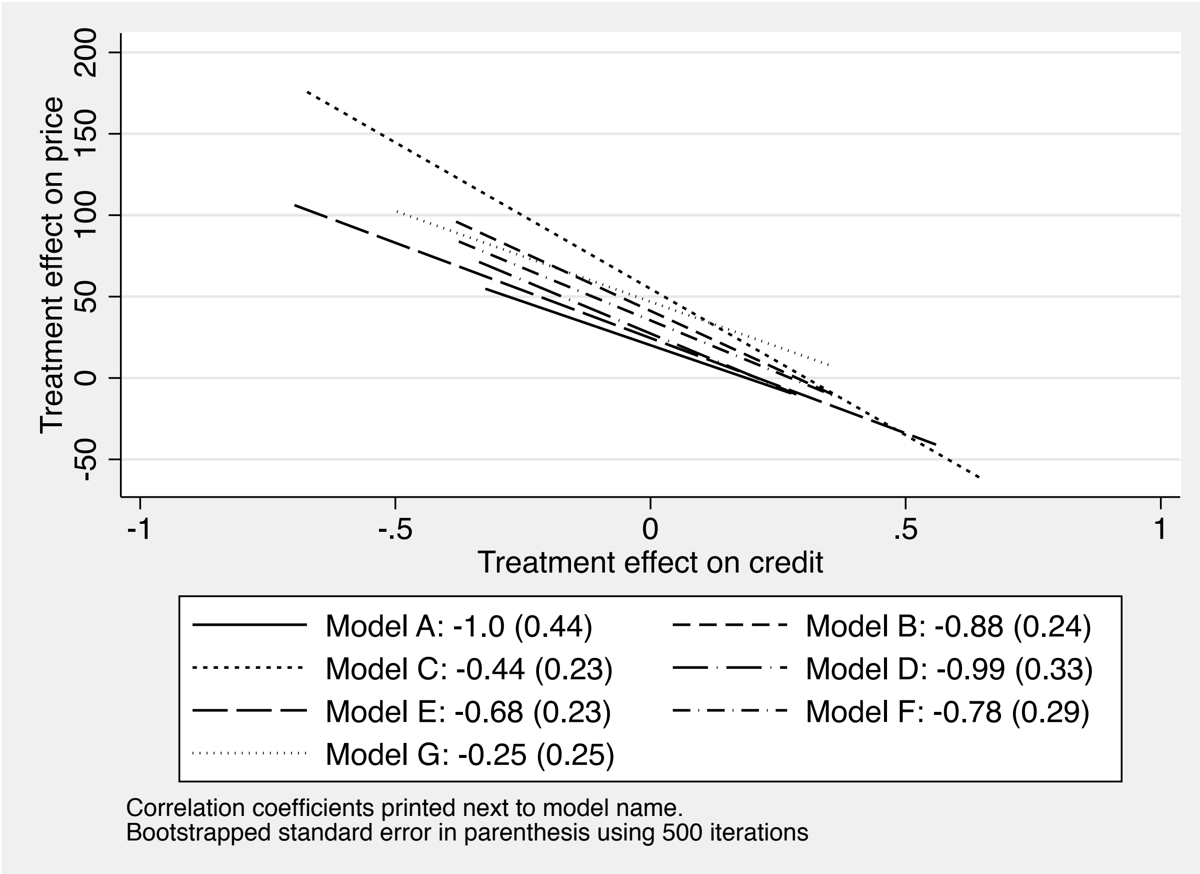


Figure 6: Substitutability, best linear fit between price and credit treatment effects estimated from each model A-G.

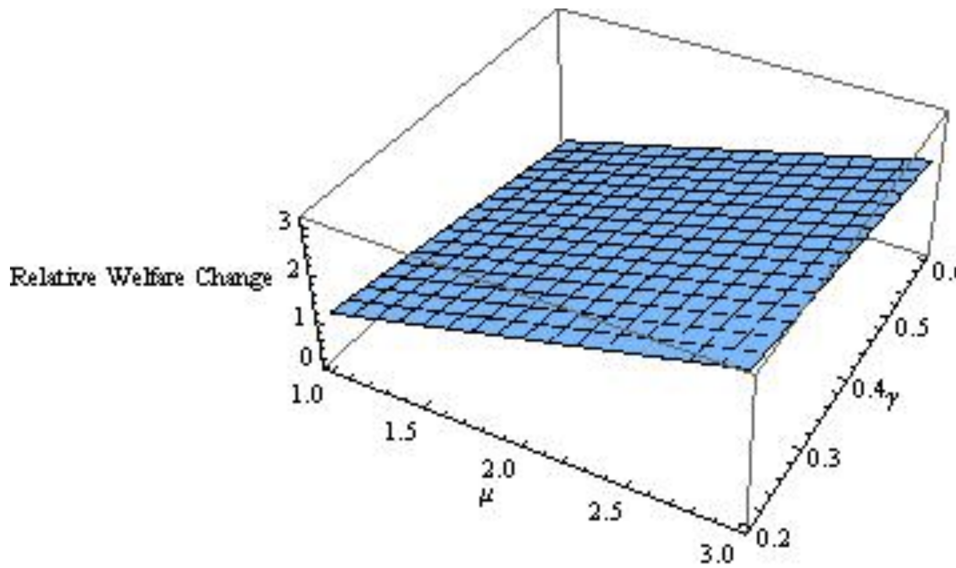


Figure 7: A welfare change in response to a marginal change in the intermediaries price in the ILT model relative to in the benchmark model.

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 trading cocoa	8.1	8.9	-0.8
			(1.2)
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	2940	3180	-240
			(750)
Per pound farmer price for Grade A (Leones)[a]	3,121.7	3,121.1	-0.6
			(47.6)
Per pound farmer price for Grades B or C (Leones)[b]	3,045.6	3,040.3	-5.3
			(32.2)
Panel C: Baseline farmer listing			
Villages operating in	4.3	4.9	-0.6
			(0.4)
Number of farmers buying from	23.3	28.4	-5.1
			(3.5)
Mean number of farmers per village	5.8	5.6	0.2
			(0.8)
Share of farmers given credit since March	0.72	0.68	0.04
			(0.07)
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	Ave. # of farmers per trader	Ave. # of competitors per trader	Pop. per square mile	Total farmers reported by traders
Panel A: Sample averages								
Mean	3.2	1.5	9.6	0.65	6.2	5.7	494	18.7
	(2.4)	(1.5)	(5.7)	(0.29)	(4.3)	(3.9)	(753)	(16.4)
Number of observations	80	80	80	80	80	80	80	80
Panel B: Balance in count of treatment traders across sample villages								
# of treatment traders			0.79	0.01	0.39	0.41	74.39	0.02
			(0.66)	(0.03)	(0.39)	(0.42)	(62.86)	(1.50)
# of study traders			-0.28	0.02	-0.30	-0.03	-32.51	5.24
			(0.41)	(0.02)	(0.30)	(0.25)	(45.87)	(1.03)
Number of observations	80	80	80	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 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. Average number of clients and competitors reported by traders in a baseline survey. Population per square mile calculated over all 2004 census enumeration areas within a 1/5th mile radius of the GPS coordinates of the village. Cost constraints prohibited collecting GPS coordinates for the population of villages.

Table 3: Farmer price response

Variable	(1) Price of Grade A	(2) Price of Grade A	(3) Price of Grade A (alt.)	(4) Price of Grade B	(5) Price of Grade C
Bonus $\in \{0, 1\}$	-5.4	-4.1	-1.4	46.03***	1.30
	(14.9)	(11.1)	(11.0)	(10.80)	(14.94)
R^2	0.9	0.9	0.9	0.88	0.88
Number of observations	1,090	1,090	1,090	527	226
Village Controls	NO	YES	YES	YES	YES
Trader Controls	NO	YES	YES	YES	YES

Notes: Robust standard errors allowing for two-way clustering at the village and trader level are shown in parenthesis. All specifications include calendar week and randomization pair fixed effects. Village controls include minimum road distance to nearest town, number of study traders, number of other treatment traders, and baseline share of farmers having ever received credit from a study trader. Trader controls are age, years working with wholesaler, and dummies for ownership of a mobile phone and a concrete floor. An observation is a shipment delivered to a wholesaler, and prices are per pound in Leones. The bonus is an increase in the trader 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 and 3. The alternative measure of price in column 3 is the total price paid to the farmer divided by weight of shipment. There were approximately 4,000 Leones to the U.S. dollar at the time of the study. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Transport cost and technology choice response

VARIABLES	(1) Pounds per shipment	(2) Pounds per shipment	(3) Unit cost	(4) Unit cost	(5) Truck use $\in \{0,1\}$
Bonus $\in \{0,1\}$	7.75***	8.20***	-10.26***	-11.38***	0.21***
	(2.18)	(2.37)	(2.58)	(2.38)	(0.05)
R^2	0.21	0.22	0.44	0.47	0.46
Number of observations	1,837	1,837	1,837	1,837	1,837
Trader Controls	NO	YES	NO	YES	YES
Village Controls	NO	YES	NO	YES	YES

Notes: Robust standard errors allowing for two-way clustering at the village and trader level are shown in parenthesis. An observation is a shipment delivered to a wholesaler. All specifications include calendar week and randomization pair fixed effects. Village controls include minimum road distance to nearest town, number of study traders, number of other treatment traders, and baseline share of farmers having ever received credit from a study trader. Trader controls are age, years working with wholesaler, and dummies for ownership of a mobile phone and a concrete floor. The control mean of pounds per shipment is 178 (s.d. = 36), Leones unit cost, 45 (s.d. = 27), and likelihood of truck use, 0.34. *** p<0.01, ** p<0.05, * p<0.1

Table 5: Credit response

Variable	(1) Lent $\in \{0,1\}$	(2) Lent $\in \{0,1\}$	(3) Amount (Leones)	(4) Amount (Leones)
Bonus $\in \{0,1\}$	0.14***	0.12***	9,771*	10,107**
	(0.03)	(0.03)	(5,209)	(4,759)
R^2	0.31	0.32	0.62	0.62
Number of observations	1,541	1,541	1,541	1,541
Trader Controls	NO	YES	NO	YES
Village Controls	NO	YES	NO	YES

Notes: Robust standard errors allowing for two-way clustering at the village and trader level are shown in parenthesis. An observation is a farmer listed by the trader in the baseline. The dependent variable in columns 1 and 2 is an indicator for whether the trader had lent to the farmer since the treatment began, asked a month after the treatment began. The control mean of this dummy was 0.12. The dependent variable in columns 3 and 4 is the amount of money lent in the past month. The control mean of this amount was 18,908 (s.d. = 52,597). All specifications include randomization pair fixed effects. Village controls include minimum road distance to nearest town, number of study traders, number of other treatment traders, and baseline share of farmers having ever received credit from a study trader. Trader controls are age, years working with wholesaler, and dummies for ownership of a mobile phone, and a concrete floor. *** p<0.01, ** p<0.05, * p<0.1

Table 6: Substitutability, baseline correlations

	(1)	(2)	(3)
Variable	ln(Price of grade A)	ln(Price of grade A)	Baseline credit share
Baseline credit share	-0.023	-0.042*	
	(0.023)	(0.023)	
Quantity supplied of grade A per trader (1,000 lbs.)			0.077***
			(0.027)
# of study traders		-0.001	0.024*
		(0.002)	(0.013)
Miles to nearest town		-0.001	-0.005
		(0.001)	(0.005)
R^2	0.020	0.093	0.080
Number of observations	51	44	80

Notes: Robust standard errors in parentheses. Observations in columns one and two are limited by the number of villages in which we observe one price in the pre-treatment period, and include those villages for which we did not observe prices post-treatment *** p<0.01, ** p<0.05, * p<0.1

Table 7: Substitutability, regression coefficients

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)
Model	A		B		C		D		E		F		G	
Outcome	Price	Credit	Price	Credit	Price	Credit	Price	Credit	Price	Credit	Price	Credit	Price	Credit
Bonus $\in \{0,1\}$	54.61	-0.32**	89.63**	-0.37**	-69.98	-0.15	70.97	-0.31*	88.34	-0.11	75.66**	-0.38***	24.24	-0.76***
	(39.30)	(0.14)	(37.89)	(0.16)	(169.63)	(0.35)	(43.81)	(0.16)	(137.03)	(0.34)	(38.33)	(0.14)	(85.40)	(0.25)
Interaction Terms														
Baseline credit share	-63.89	0.60***	-72.61	0.59***	522.41	0.46	-78.95	0.60***	80.01	0.94	-54.07	0.58***	576.12	-0.49
	(50.95)	(0.21)	(49.01)	(0.22)	(476.57)	(1.49)	(52.21)	(0.21)	(528.11)	(1.28)	(48.73)	(0.22)	(460.93)	(1.32)
Baseline credit share^2					-1,327.95	3.24			-558.78	2.23			-1,446.56	4.48
					(1,208.54)	(3.57)			(1,265.06)	(3.19)			(1,084.05)	(3.29)
Baseline credit share^3					799.21	-3.11			402.44	-2.49			896.40	-3.53
					(782.44)	(2.34)			(787.57)	(2.10)			(683.43)	(2.16)
# of study traders			-13.55	0.04*	-83.09	0.27					-16.21*	0.04*	-105.26	0.34
			(9.44)	(0.02)	(65.81)	(0.20)					(9.21)	(0.02)	(75.02)	(0.23)
# of study traders ^{2}					8.49	-0.06							13.15	-0.07
					(12.91)	(0.04)							(14.58)	(0.05)
# of study traders ^{3}					-0.41	0.00							-0.68	0.00*
					(0.75)	(0.00)							(0.84)	(0.00)
# of treatment traders			19.88	-0.04	273.66**	-0.23					23.59	-0.04	257.86**	0.02
			(14.49)	(0.03)	(118.45)	(0.25)					(14.91)	(0.03)	(111.83)	(0.24)
# of treatment traders^2					-71.61*	0.07							-67.61*	-0.01
					(36.89)	(0.07)							(34.70)	(0.07)
# of treatment traders^3					5.90*	-0.01							5.65*	-0.00
					(3.27)	(0.01)							(3.08)	(0.01)
Miles to nearest town			0.06	-0.00	16.01	-0.13	-0.08	-0.00	-18.61	-0.14				
			(2.88)	(0.01)	(40.35)	(0.09)	(2.47)	(0.01)	(38.17)	(0.09)				
Miles to nearest town^2					-0.92	0.01			2.57	0.01				
					(3.45)	(0.01)			(3.18)	(0.01)				
Miles to nearest town^3					0.02	-0.00			-0.07	-0.00				
					(0.08)	(0.00)			(0.07)	(0.00)				
R^2	0.89	0.33	0.89	0.34	0.90	0.38	0.89	0.33	0.89	0.37	0.89	0.34	0.90	0.36
Number of observations	1,090	1,541	1,090	1,541	1,090	1,541	1,090	1,541	1,090	1,541	1,090	1,541	1,090	1,541
Trader Controls	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES	YES

Robust standard errors allowing for two-way clustering at the village and trader level are shown in parenthesis. Price and credit regressions are each weighted by the the inverse of the number of observations per village. Trader controls are age, years working with wholesaler, and dummies for ownership of a mobile phone and a concrete floor. *** p<0.01, ** p<0.05, * p<0.1

Table 8: Substitutability, predicted treatment effect correlations

Model	A	B	C	D	E	F	G
$\hat{P}$	-1.0	-0.88	-0.44	-0.99	-0.68	-0.78	-0.25
	–	(0.24)	(0.23)	(0.33)	(0.23)	(0.29)	(0.25)
Test Statistic	-2.27	-3.56	-1.93	-3.03	-2.95	-2.68	-0.93

Notes: ρ gives the correlation coefficient between the predicted treatment effect on price and on credit for each model estimated using weights equal to the inverse number of observations per village. Bootstrapped standard errors estimating using 500 iterations, resampling price and credit samples with replacement, are in parenthesis. The test statistic is ρ divided by its standard error. Model A includes only baseline credit share; Model B includes baseline credit share, number of study traders, number of treatment traders, and minimum road distance to nearest town. Model D includes only baseline credit share and minimum road distance, and Model F includes only baseline credit share, number of study traders and number of study traders. Model C includes a cubic for all terms in B, E includes a cubic for all terms in D, and G includes a cubic for all terms in F.

Table 9: 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 observed before the November decrease in the international price. Elasiticty gives the percentage reduction in price for a 1 percentage point increase in the defect.

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