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ARTICLE

Why agricultural insurance may slow down agricultural development

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Abstract

How does agricultural insurance affect the modernization of farming in low income countries? We focus on institutional contexts without formal contract enforcement, where smallholders cannot access modern inputs via markets. Instead, farmers can engage in relational contracting with traders to sell their crop and gain access to inputs (as an advance in-kind payment). Although conventional theory assumes that insurance "crowds in" modern inputs by attenuating investment risk, we demonstrate that insurance reduces the number of farmers receiving modern inputs from traders. Insurance also reduces the quantity of inputs that traders provide to farmers who remain in a relationship. Insurance may impede the uptake of modern inputs when institutions are imperfect.

KEYWORDS

formal and informal institutions, modern agricultural inputs, relational contracting

JEL CLASSIFICATION

D02, O12, Q12, Q14

1 | INTRODUCTION

Imperfect contract enforcement is a common feature of the institutional context in low-income countries. If formal contract enforcement is impossible or impractical, contracting parties tend to design informal arrangements to guarantee performance. The promise of future rents is an important element of informal contract enforcement mechanisms. If the present value of future cooperation outweighs the short-term benefits of reneging on the agreement, an informal contract is said to

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be self-enforcing. In this paper we consider a setting where relational contracts are the dominant principle governing the flow of commercial transactions—as in rural Africa—and use theory to probe the complex and counterintuitive relationship between insurance for smallholders and the modernization of farming (or the uptake of modern inputs).

The majority of the world's poor live in rural areas, and their economic fate depends on the performance of the agricultural sector (e.g., Dercon & Gollin, 2014; World Bank, 2007).[1] In the context of a rapidly growing and urbanizing population, and a changing climate, policies aiming to intensify and modernize smallholder agriculture have emerged as a top priority. This process requires the diffusion of modern agricultural technology. However, the adoption of new technologies—including the uptake of improved crop varieties, fertilizer, and agrochemicals—remains low and uneven, especially in Africa (Sheahan & Barrett, 2014). The literature proposes several reasons for incomplete technology adoption. These include "classical explanations" such as lack of knowledge and access to credit, or limited availability of inputs. More recent insights are based on behavioral economics (Foster & Rosenzweig, 2010) or the presence of low-quality counterfeit inputs on rural markets (Bold et al., 2017).

Another well-known impediment to modernization is lack of access to insurance. Vagaries of the weather and market risk induce farmers to use "*risk-avoidance, risk-diversification and informal sharing practices that are either costly or offer inadequate risk protection*" (Miranda & Farrin, 2012, p. 391). This may imply a preference for "low-return, low-risk" farming strategies over "high-return, high-risk" strategies supported by external inputs. Eliminating downside risk may therefore "crowd in" investments in modern technologies—unlocking first-order increases in productivity (Emerick et al., 2016; Karlan et al., 2014). Although the introduction of index insurance increased access to formal insurance products for smallholders in many low-income countries, take-up rates remain low—typically hovering below 10% of the target population. This reflects challenges implied by basis risk, liquidity constraints, and low trust in insurance providers (e.g., Carter et al., 2017; Cole & Xiong, 2017). In response, nearly all agricultural insurance projects are heavily subsidized.

In this paper we analyze the complex relationship between these two themes—the introduction of insurance and the modernization of agriculture (or the uptake of modern inputs). We contribute to the literature by focusing on two important elements of the institutional context: imperfect input and factor markets combined with incomplete opportunities for formal contracting. Farmers lack liquidity because of savings constraints and credit market rationing, and rely on traders for access to (prefinanced) modern inputs. The absence of formal contracting opportunities, supported by third-party enforcement, implies that agreements between traders and farmers must be self-enforcing. We develop a two-tier market structure model, with interlinked spot markets and relational contracts, and extend the existing literature by incorporating stochastic production and risk aversion.

This paper fits in an emerging literature that takes intermediation by traders seriously (e.g., Antras & Costinot, 2011; Bardhan et al., 2013; Fafchamps, 2004, 2010) and is at the interface of two literatures. First, we derive new insights about the impacts of agricultural insurance. Adoption rates of (index) insurance programs are typically low, which implies that the majority of farmers forego potentially large welfare gains from insurance. In addition to static utility gains from consumption smoothing, insurance may generate dynamic benefits—affecting both ex ante and ex post risk management (e.g., Cai, 2016; Karlan et al., 2014; Mobarak & Rosenzweig, 2013; Walker & Ryan, 1990).[2] A large literature explores how to modify insurance contracts to mitigate problems due to basis risk and lack of liquidity, knowledge, or

[1]Economic growth in agriculture is an effective way to lift people out of poverty because of its multiplier effects in early stages of development and because income growth originating in agriculture raises income of the poor more than growth originating elsewhere in the economy (Christiaensen et al., 2010; Haggblade et al., 2007; Ligon & Sadoulet, 2007). Moreover, due to various forward and backward linkages, the modernization of agriculture promotes overall economic modernization and structural change (e.g., McArthur & McCord, 2017).

[2]For example, Janzen and Carter (2019) find that insurance reduces reliance on "cutting consumption" and "selling assets" as costly ex-post coping strategies, which has implications for the risk of tumbling into a "poverty trap." Hill et al. (2019) observe that an effect on ex ante risk (farm) management implies an ex post (expected) income effect—relaxing future liquidity constraints thus promoting investments. Finally, insurance may transform local capital markets. It can reduce risk rationing on credit markets, as smallholders no longer fear losing their land (Boucher et al., 2008). In contexts without collateral, insurance reduces risk for lenders—reducing risk premiums and increasing the affordability of loans for smallholders.

trust. The premise in the literature is that the introduction of insurance is desirable but difficult. Our paper adds a novel perspective by showing that the introduction of insurance products may reduce productivity of smallholder farming and increase inequality within rural communities.

Second, the paper contributes to the small literature on relational contracting in low-income agriculture, where informal mechanisms are used to guarantee performance and expand the range of transaction possibilities (compared to spot market trading).[3] Swinnen et al. (2015) and Kuijpers and Swinnen (2016) analyze technology transfer through vertical coordination in a weakly institutionalized setting. They discuss how opportunities for farmer and trader hold-up affect bargaining power and rent distribution, and the role of asset-specificity therein, as well as the timing and size of relational surplus. For example, they argue that imperfect competition on product markets may foster relational contracting and technology transfer by reducing farmer hold-up risk (i.e., by reducing returns of reneging by farmers). This is empirically confirmed for the case of coffee farming in Rwanda by Machiavello and Morjaria (2021). Less competition between bean-processing coffee mills on local coffee markets benefits the farmer and increases the value of his output through enhanced access to mill-provided inputs.[4]

Our work extends existing models on relational contracting by introducing several novel features. We introduce stochasticity in outcomes, which increases the temptation to renege in some states of the world. For example, the farmer's temptation to side sell is greater when the realized price is exceptionally high. However, stochasticity also facilitates cooperation by enabling traders to absorb farmer risk if farmers are risk averse.[5] We use a two-tier market structure, where traders and farmers can meet on spot markets or engage in relationships. Insurance affects spot market outcomes. Finally, we introduce heterogeneity in risk preferences across farmers and study the impact of insurance on modern inputs use by farmers. We consider both the amount of inputs accessed by farmers who are in a relationship with a trader (the intensive margin) and changes in the number of farmers contracting with traders (the extensive margin). Our main result is that the introduction of agricultural insurance improves "spot market outcomes" for farmers who are not in a relationship with a trader. This undermines the scope for relational contracting: Fewer farmers receive modern inputs from traders, and farmers remaining in a relation receive fewer inputs—impeding the modernization of smallholder farming.

This paper is organized as follows. In Section 2 we sketch the foundations of our model of interacting rural markets, where producers and traders interact. We distinguish between spot market exchange and relational contracting. In Section 3 we introduce insurance and explore how this affects the extensive and intensive margin of modern input use. We argue that, for plausible assumptions, the expansion of insurance crowds out modern inputs, shifting both the intensive and extensive margin inward. This lowers the value of agricultural production. The conclusion and discussion ensue.

2 | SPOT MARKETS AND RELATIONAL TRADING

2.1 | Introducing the general equilibrium model and the local labor market

Consider a stylized model with N farmers and M traders. Traders sell the produce to a final consumer (or processor). Farmers and traders are randomly matched on a spot market where they bargain about the division of the surplus associated with crop trading but can also engage in a so-called

[3]The literature contains several nonagricultural applications of relational contracting in low-income countries, including McMillan and Woodruff (1999), Banerjee and Duflo (2000), Banerjee and Munshi (2004), Andrabi et al. (2006), and Munshi (2011).

[4]Other papers on relational contracting in agriculture include Machiavello and Morjaria (2015), who study learning about the agent's type and find that relational contracts can be nonstationary. Another paper is Casaburi and Machiavello (2019), who study infrequent payments as a savings commitment device for smallholders with time-inconsistent preferences, when buyers are heterogenous in their ability to commit to delayed payment. Only the most credible buyer, with the weakest incentive to renege, can commit to pay infrequent payments in equilibrium and is able to charge a fee for the commitment service it provides.

[5]The idea that the trader can absorb farmer risk (at a cost to the farmer) is akin to the idea that large landowners can smooth income of landless workers through labor tying (e.g., Bardhan, 1983).

"relational contract." In a relationship, parties informally agree to work together in producing and exchanging goods, and cooperation can be sustained by the promise of future rents. Spot markets and relational contracts coexist in smallholder farming (e.g., Fafchamps, 2004; Swinnen et al., 2015). We assume the following.

A1: *Traders are risk neutral.*

A2: *Farmers can only access modern inputs via traders.*

Traders provide two possible services: They can absorb risk and provide modern inputs. The trader has access to financial markets and can hedge risk, and therefore is modeled as risk neutral. This is an extreme assumption that is unlikely to hold in most circumstances (because traders also face financial market imperfections). What is needed for mutually profitable risk transferring between farmer and trader is simply that the latter is less risk averse than the former. Traders can also prefinance and provide modern inputs, which we assume the farmer cannot access himself. There are several possible reasons for this. Agro-dealers may be unavailable within a reasonable distance, or, if they are present, there tend to be frequent stock outs. Sometimes modern inputs are only traded in large quantities that are unattractive for smallholders. Farmers may also be uncertain about the quality of inputs that are offered (stories about counterfeit or low-quality inputs are rampant throughout Africa—see Bold et al., 2017, Ashour et al., 2019, and Michelson et al., 2021). Perhaps most importantly, smallholders can be liquidity-constrained because they are unable to save for the purpose of investments in inputs (e.g., Duflo et al., 2011; Dupas & Robinson, 2013). Nevertheless, it is clear that the assumption that farmers cannot independently access input markets is a strong one.

A3: *Farmers are risk averse, with a constant absolute risk aversion (CARA) "exponential utility" function:*[6] $U(y_i) = -\exp^{-a_i y_i}$.

In A3, exp refers to the exponential constant, a_i is the coefficient of absolute risk aversion for farmer i, and y_i denotes farmer income, or the sum of off-farm income and agricultural income (see below).

A4: *Parameter a_i is common knowledge for both farmers and traders.*

Higher values of parameter a imply greater risk aversion, and we will demonstrate that only farmers with a coefficient of absolute risk aversion above threshold level a^* will engage in contract farming (see below). To simplify the analysis, we refrain from studying asymmetric information about farmer type.

A5: *Parameter a_i is uniformly distributed between zero and $\bar{a}: a_i \in U(0, \bar{a})$.*

Assumptions A3–A5 imply that $\frac{a*}{\bar{a}}N$ farmers operate on the spot market, and $\frac{\bar{a}-a*}{\bar{a}}N$ are involved in relational contracting. We solve the threshold value a^* below.

Each farmer i divides her time endowment T between off-farm work L, earning a wage w, and producing food, with effort level e. Off-farm income Y_i^{off} is given by

$$Y_i^{\text{off}} = wL_i = w(T - e_i). \tag{1}$$

Farmers operating on the spot market allocate $\hat{e}$ units of effort to producing crops, whereas farmers engaged in relational contracting allocate e^* to producing crops. Here, $\hat{e}$ and e^* refer to the optimal level of effort (to be determined below) in case of spot market trading and relational contracting, respectively. For simplicity, but without loss, farmers cannot engage both in relational contracting and spot market trading (but they can combine either activity with off-farm labor supply). Hence,

$$T = L_i + e_i, \text{where } e_i = \hat{e}_i \text{ if } a_i \leq a^* \text{ and } e_i = e^* \text{ if } a_i > a^*. \tag{2}$$

Outcomes $\hat{e}$ and e^* depend, among others, on the prevailing wage rate, $w: \hat{e} = \hat{e}(w,..)$ and $e^* = e^*(w,..)$, with $\hat{e}'(w..) < 0$ and $e^{*\prime}(w,..) < 0$. Below we show that optimal labor supply for farmers

[6]This assumption is unimportant. Qualitatively similar results are obtained when we use a constant relative risk aversion utility function.

on the spot market depends on risk preferences, which is not true for farmers engaged in relational contracting. We focus on the case where wages are given (perfectly elastic demand for labor).

3 | SPOT MARKET TRADING

Random matching on the (local) spot market describes the "default outcome" for farmers and traders who are not in a relationship. We assume the farmer has no access to modern inputs (see A2) and visits the local market to sell her crop output to one of the traders who is present. These smallholders are referred to as spot market farmers in what follows. Denote the value of agricultural production (food) by $V(e)$.

A6: $V_e > 0$ *and* $V_{ee} < 0$.

This value is stochastic, perhaps determined by the vagaries of rainfall or by stochastic demand. Farmer i can raise the expected value of agricultural production by allocating extra effort (Δe_i) to that activity at the expense of off-farm income, $-w\Delta e_i$.

A7: *V(e) is stochastic*: $V(e) = (1+z)\overline{V}(e)$,

where z is a zero-mean random variable with variance $\rho^2 : E(z) = 0$ and $E[z]^2 = \rho^2$, and where $\overline{V}(e)$ denotes the expected value of output.

A8: *Variable z follows a triangular continuous probability distribution with a lower limit l, upper limit h, and mode m = 0, where l ≤ 0 ≤ h.*[7]

The mean of the triangular probability equals $\frac{l+m+h}{3} \equiv \frac{l+h}{3}$; the variance:

$$\frac{l^2 + h^2 + m^2 - l*\mathrm{h} - \mathrm{l}*\mathrm{m} - \mathrm{h}*\mathrm{m}}{18} \equiv \frac{l^2 + h^2 - lh}{18}. \tag{3}$$

In the spot market model, l and h are set such that $\frac{l+m+h}{3} \equiv \frac{l+h}{3} = 0$. Thus, $E(V(e)) = \overline{V}(e)$ with variance $\sigma^2(V(e)) = \rho^2 \overline{V}^2(e)$. After the realization of $V(e)$, trader and farmer bargain over the share of the surplus that is paid to the farmer.

A9: *Farmers do not have transport costs and will always sell their crop (i.e., it has an "outside value" of zero). We assume bilateral Nash bargaining between trader and farmer over the surplus.*

Given A9, payment p^N solves the following Nash bargaining problem:

$$p^N = \arg\max_p \left\{ (V(e) - p)^{\beta} (p)^{1-\beta} \right\} \tag{4}$$

Where p is the price paid to the farmer and β is an exogenous measure of the bargaining power of the trader. The solution implies:

$$\frac{\beta}{1-\beta} = \frac{V(e) - p}{p}, \tag{5}$$

so that:

$$p^N = (1-\beta)V(e). \tag{6}$$

The ex-ante expected payoffs for the trader after bilateral bargaining (BB) are therefore:

$$\pi_T^{\mathrm{BB}} = \beta \overline{V}(e). \tag{7}$$

[7]We use a triangular probability distribution as it facilitates distinguishing between so-called *yield-enhancing* and *risk-reducing* inputs—see the analysis below.

The certainty equivalent (CE) of farmer i reads as:[8]

$$\mathrm{CE}_i = \pi_F^{BB} = p^N + Y_i^{off} - \frac{1}{2}a_i\rho^2 p^{N2}(e) = (1-\beta)\overline{V}(e) + w(T-e) - \frac{1}{2}a_i(1-\beta)^2\rho^2\overline{V}^2(e). \tag{8}$$

Farmers choose effort to maximize (8). The farmer's optimal effort level with spot market trading, $\widehat{e}$, is implicitly defined by:

$$(1-\beta)\overline{V}' = w + a_i(1-\beta)^2\rho^2\overline{V}\overline{V}'. \tag{9}$$

In Appendix A we show that optimal effort is decreasing in w, absolute risk aversion parameter a, the variance of the value of output ρ^2, and in the trader's bargaining power β. The BB model rests on the simplifying assumption that farmers and traders are randomly matched after production has taken place. More efficient outcomes, where traders provide farmers with productivity-enhancing modern inputs, are within reach if farmers and traders play a repeated game.

4 | RELATIONAL CONTRACTING: SETTING UP THE MODEL

A trader–farmer pair can start a relationship to support cooperative behavior. We focus on a so-called stationary subgame perfect equilibrium where the trader repeatedly offers the same contract to the farmer. Levin (2003) proved that if optimal relational contracts exist, then there also exist stationary contracts that are optimal—there is no loss of generality from focusing on stationary contracts (but not all optimal contracts must be stationary).

The sequence of events in each period is as follows. The trader offers to the farmer a contract that involves the following components: a fixed payment upon delivery regardless of the prevailing spot market price (R), a certain amount of modern inputs (x), and a prescribed level of effort for the farmer (e^*). If the farmer rejects, the game ends and the trader and farmer receive their outside options as spelled out in (7) and (8). If the farmer accepts, the trader provides the inputs and the game proceeds to Stage 2. At Stage 2, the farmer decides whether or not to side sell the inputs. If the farmer side sells the inputs ("cheats"), the trader terminates the relationship, the game ends, and both players turn to the spot market. If the farmer does not cheat, the game moves to Stage 3, where uncertainty about the value of production is resolved. The farmer now decides whether or not to side sell his crop (if spot market prices are high), and the trader decides whether or not to renege on the agreement (if spot market prices are low). If a player reneges, the game ends and both players turn to the spot market. Else, the game moves to Stage 4 where the contract terms are enforced. The farmer receives fixed payment R and the trader receives the crop. At Stage 5, all payoffs are realized.

We assume the following:

A10: *The trader terminates the relation in case the farmer side sells part of his crop, and the farmer does the same if the trader reneges and pays less than promised. Information about defection is immediately and completely shared with all market participants.*

A10 ensures that cooperation is supported by the threat of terminating the relationship. This draconian strategy is only credible if there are no relationship-specific gains from trade, which is likely a realistic assumption in the context of smallholder trade in staples such as wheat, maize,

[8]Note that with CARA utility, for small gambles and assuming that the gamble is a bounded random variable, the risk premium π (i.e., the maximum amount an individual would pay to avoid gamble ϵ, with $E[\varepsilon]=0$ and $E[\varepsilon^2]=\sigma^2$) equals $\pi \approx \frac{1}{2}\sigma^2 a$ (Back, 2016). With CARA utility and a gamble that is normally distributed, the risk premium would be exact, that is, $\pi = \frac{1}{2}\sigma^2 a$.

and rice.[9] A10 implies that cheating one partner implies foregoing all opportunities of future cooperation—defecting today implies relegation to the spot market in all future periods.[10] The absence of relationship-specific gains from trade and full information sharing implies the number of market participants should not be "too small" (the absence of alternative trading partners could induce parties to engage in relationship-specific investments) but also not "too large" (else full information sharing could result in information overload).[11]

As mentioned in the sequence of events, above, the trader offers a fixed price R before uncertainty about the realization of V is resolved and thus absorbs risk of the farmer.

A11: *The trader can observe the effort level of the farmer with which he is in a relationship. He makes payment of R conditional on the supply of the agreed level of effort, which is set by the trader,* e^*.[12]

Importantly, the trader also may provide modern inputs to the farmer (A2), which, combined with farmer effort, determine the expected value of agricultural production.

A12: *Modern inputs and labor are perfect complements in production.*[13]

Modern inputs affect demand for effort by the farmer. Labor and modern inputs may be complements or substitutes in the agricultural production process. Herbicides and labor are substitutes, as the application of herbicides enables farmers to allocate less effort to weeding (e.g., Gianessi & Williams, 2011). However, most modern inputs raise the productivity of labor (Binswanger & Rosenzweig, 1986). Additional effort is needed for input application and harvesting (Fischer et al., 2015), and larger households, with greater time endowments in a context of imperfect labor markets, are more likely to use improved inputs (Sheahan & Barrett, 2014). Using a generalized perfect complements production function, with parameters m and n, production with relational contracting is given by:

$$V^{rc} = V^{rc}(x, e^*) = (1 + z_x)\overline{V}^{rc}(x, e^*) = (1 + z_x)(\min(mx, ne^*))^{\gamma}, \text{with } \gamma < 1.$$

where V^{rc} denotes value of relational contracting, $\overline{V}^{rc}$ is the expected value of relational contracting, z_x is a zero-mean random variable with variance $E[z_x]^2$, e^* is effort supply with relational contracting, and $\gamma < 1$ is a parameter capturing decreasing returns to scale.

A13: *The trader sets x, and demands that the farmer supplies the effort level* e^* *consistent with the perfect complements production function.*

The trader sets e^* to maximize the expected value of production, which gives the following technical relationship between effort and inputs:

[9]Levin (2003) shows that termination of the relationship may not be renegotiation proof if there are relationship-specific gains from trade between trader and farmer. If termination means destroying potential surplus. Parties might be tempted to forgive each other because there are future gains from cooperation (but then the threat of termination is no longer credible). One solution is to continue with a contract after a deviation but shift the terms of trade to hold the deviator at his reservation utility—still punishing him but without destroying the surplus. Importantly, the qualitative results of our analysis are unaffected if we would assume trading partners followed such a temporary punishment strategy instead of relationship termination.

[10]We assume coordinating on joint punishment of defectors is incentive compatible for parties. This may be because reneging today is a strong signal of the propensity of the same trader or farmers to renege again tomorrow (i.e., to be of the "bad type"). Alternatively, parties may form a coalition with second-order punishment or reputation costs for individuals who team up with the wrong party (e.g., ostracism, expulsion from the club, reputation cost—see Aoki, 2001).

[11]As an illustrative example, consider the case of (weekly) local Ethiopian wheat markets. According to Do Nascimento Miguel (2022), 39 traders and 560 farmers visit on an average market day. This seems consistent with our assumption of sufficiently many potential partners for trading and sufficiently few potential partners for information sharing. Approximately half of the farmers on these markets are in a relationship with a trader, often including advance in-kind payments.

[12]In reality, of course, less-than-perfect risk absorption is also possible, with the trader offering a price exceeding the spot market price when the latter is "low" and a price below the spot market price when the latter is "high." In a qualitative sense, this leaves the analysis below unaffected.

[13]The model below can be rewritten to accommodate the case of labor and modern inputs as substitutes, but this model is comparable to the case we explore as the trader will always make input provision conditional on a minimum level of farmer effort.

$$x = \frac{e^{*} n}{m} = \psi e^{*}. \tag{10}$$

For simplicity we normalize unit costs of modern inputs x to 1. Recall that in case of spot market trading we assume a triangular probability distribution for z, with mode $m = 0$. If the famer does not have access to inputs, values of l and h are such that $\frac{l+h}{3} = 0$.[14] In the relational contracting model, instead, we assume that the uptake of modern inputs x will shift up either upper bound h of the distribution or shift up lower bound l. Specifically, we distinguish between two types of inputs. Risk-reducing inputs shift up lower bound l, and increase the value of production under adverse conditions (e.g., during droughts). We assume $l^{'}(x) > 0$ and $l^{''}(x) \leq 0$. An example of a risk-reducing input is drought-resilient crop varieties. In contrast, yield-enhancing inputs shift up the upper bound h when rainfall conditions are favorable: $h^{'}(x) > 0, h^{''}(x) < 0$. Examples are hybrid seed varieties with superior growth during favorable conditions or fertilizers.

For convenience, we rewrite the production function for spot market trading. The production function with relational contracting is identical to the one for spot market farmers when no modern inputs are used:

$$\{V^{rc}(e) | x = 0\} = (1 + z)\overline{V}(e), \tag{11}$$

where, as above, z is a zero-mean random variable with variance $\rho^2 : E(z) = 0$ and $E[z]^2 = \rho^2$. If the trader provides inputs:

$$\{V^{rc}(e) | x > 0\} = (1 + z_x)\overline{V}(e). \tag{12}$$

We define $z_x = \frac{l(x)+h}{3}$ for risk reducing inputs, with $l(x) < 0,\ h > 0,$ and $E(z_x) > 0$ and $E[z_x]^2 < \rho^2$, and $z_x = \frac{l+h(x)}{3}$ for yield-enhancing inputs, with $E(z_x) > 0$ and $E[z_x]^2 > \rho^2$. Although both types of inputs increase the expected value of output, risk-reducing inputs reduce the variance of the value of output and yield-enhancing inputs increase it.

To sum up, for $x > 0$, effort levels are determined by inputs ($e^{*} = x/\psi$) and the expected value of output becomes:

$$E(V^{rc}(e)) = \overline{V}(e) + \frac{l(x)+h}{3}\overline{V}(e), \text{with} \frac{l(x)+h}{3} > 0, \text{and} \tag{13}$$

$$E(V^{rc}(e)) = \overline{V}(e) + \frac{l+h(x)}{3}\overline{V}(e), \text{with} \frac{l+h(x)}{3} > 0, \tag{14}$$

for risk-reducing and yield-enhancing inputs, respectively.

A14: *Using modern inputs makes ex ante economic sense: The increase in expected output exceeds the cost of using inputs for some range of x values. For risk reducing inputs*:

$$E\{(V^{rc}(e)) | x > 0\} - E\{(V^{rc}(e)) | x = 0\} = \frac{\mathrm{l}(x) - 1}{3} > x.$$

For yield enhancing inputs:

[14]Blouin and Macchiavello (2019) study strategic default between coffee mills and foreign buyers, occurring when market (or production) conditions change sufficiently to place the relational contract outside its self-enforcing range. In our case, if an unexpected output or price shock places the value of production, V, either below lower bound l or above upper bound h, then strategic default occurs (by, respectively, the trader or the farmer). We think of bounds l and h as the expectations of possible future values, shared by farmer and trader. These expectations may be (but need not be) based on experience

$$E\{(V^{\mathrm{rc}}(\mathrm{e}))|x>0\}-E\{(V^{\mathrm{rc}}(e))|x=0\}=\frac{h(x)-h}{3}>x.$$

4.1 | Incentive compatibility constraints and participation constraints

We focus on the case of risk-reducing inputs (the case of yield-enhancing inputs is presented in Appendix B, discussed below). Expected profits for the trader with a relational contract are:

$$\pi_T^{RC}=\overline{V}(e^*)+\frac{l(x)+h}{3}\overline{V}(e^*)-R. \tag{15}$$

The trader supplies inputs x at the start of the season and subtracts the value of (pre-financed) input costs from the negotiated contract price R, where payment of R is conditional on the farmer supplying the agreed-upon effort level e^*. The participation constraint for the trader specifies that expected profits from relational contracts should exceed expected profits under spot market trading:

$$\pi_T^{RC}=\overline{V}(e^*)+\frac{l(x)+h}{3}\overline{V}(e^*)-R\geq\pi_T^{\mathrm{BB}}=\beta\overline{V}(\widehat{e}_i). \tag{16}$$

This defines an upper bound for the payment R:

$$R\leq\overline{V}(e^*)+\frac{l(x)+h}{3}\overline{V}(e^*)-\beta\overline{V}(\widehat{e}_i). \tag{PCT}$$

Similarly, the farmer's participation constraint says that expected income under relational contracting should exceed the CE of spot market trading:

$$\pi_F^{RC}=R+w(T-e^*)-x\geq\pi_F^{\mathrm{BB}}, \tag{17}$$

which defines a lower bound for payment R:

$$R\geq\left(w(e^*-\widehat{e}_i)+(1-\beta)\overline{V}(\widehat{e}_i)+\psi e^*-\frac{1}{2}a_i(1-\beta)^2\rho^2\overline{V}^2(\widehat{e}_i)\right). \tag{PCF}$$

Next, we consider incentive compatibility constraints (ICC), which refer to the decision by traders and farmers to comply with the agreed-upon contract. Consider the farmer's problem first, for whom two ICCs should be satisfied. The first one concerns the allocation of effort: a decision before effort has been allocated, before uncertainty of crop value is resolved but after inputs have been allocated by the trader. According to the relational contract, the farmer should work $e^*=x/\psi$ units of time on her plot (recall A13). However, she is tempted to side sell part of the inputs (say: λx), work fewer hours on the plot $[e^{'}=(1-\lambda)x/\psi]$, and accept off-farm employment for wages for the extra time. Because effort choice by the farmer is observed by the trader, a consequence of side selling inputs is that the trader will terminate the relation. The farmer therefore will sell her crop on the spot market. A farmer side selling inputs earns:

$$\pi_F^{ss1}=(1-\beta)\overline{V}(e^{'})+w(T-e^{'})+\lambda x-\frac{1}{2}a_i(1-\beta)^2E(z_x)^2\overline{V}^2(e'). \tag{18}$$

Because $\lambda x=x-e'\psi$ and $\{V^{rc}(e)|x>0\}=(1+z_x)\overline{V}(e)$, full income when side selling modern inputs equals:

$$\pi_F^{ss1} = (1-\beta)(1+z_x)\,\overline{V}\left(e^{'}\right) + w\left(T-e^{'}\right) + x - e'\psi - \frac{1}{2}a_i(1-\beta)^2 E[z_x]^2(1+z_x)^2\overline{V}^2(e') \tag{18}$$

Farmers choose effort $e^{'}$ to maximize the expression above:

$$(1-\beta(1+z_x))\overline{V}^{'} = w + \psi + a_i(1-\beta)^2\rho^2(1+z_x)^2\overline{VV}^{'}. \tag{19}$$

The first incentive compatibility constraint for the farmer therefore is:

$$\pi_F^{ss1} + \frac{(1-r)\pi_F^{\mathrm{BB}}}{r} \le R - x + w(T-e^*) + \frac{(1-r)(R + w(T-e^*) - x)}{r}, \tag{ICCF1}$$

where r is the (common) discount rate for traders and farmers. ICC-F1 defines a lower boundary for the payment R to prevent side selling of inputs. The first term on the left-hand side (LHS) captures the one-time return from defection (side selling modern inputs, working additional hours off farm, selling the crop on the spot market). The second term is the discounted value of the CE from future trading on the spot market. The sum of these terms should not exceed the net present value of compliance, or receiving $R - x + w(T - e^*)$ now, followed by the discounted flow of benefits associated with relational contracting in the future.

The second ICC addresses side selling of the crop that is produced after uncertainty about crop value is resolved. If the realized value of the crop on the spot market is "high," the farmer is tempted to side sell his crop rather than accepting the crop for the pre-agreed price R that is in the relational contract. The maximum income that a reneging farmer can earn by side selling his crop occurs when the spot market price takes the maximum value:

$$\pi_F^{ss2} = (1-\beta)(1+h)\overline{V}(e^*) + w(T-e^*), \tag{18}$$

so that the second ICC for the farmer reads as follows:

$$\pi_F^{ss2} + \frac{(1-r)\pi_F^{\mathrm{BB}}}{r} \le R - x + w(T-e^*) + \frac{(1-r)(R + w(T-e^*) - x)}{r}. \tag{ICCF2}$$

Which constraint is binding, ICC-F1 or ICC-F2, and defines the minimum payment R that is part of the agreement? This depends on the size of π_F^{SS1} relative to π_F^{SS2}. ICC-F1 binds when $\pi_F^{SS1} > \pi_F^{SS2}$, or when:

$$\begin{aligned}&(1-\beta)(1+z_x)\overline{V}\left(e^{'}\right) - (1-\beta)(1+h)\overline{V}(e^*) + w(e^* - e') + x - e'\psi \\ &-\frac{1}{2}a_i(1-\beta)^2E(z_x)^2(1+z_x)^2\overline{V}^2(e') > 0\end{aligned}$$

Whether ICC-F1 or ICC-F2 binds is ambiguous, but some intuitive insights follow from this condition. First, if crop value is highly volatile so that large price peaks are possible (i.e., h is "large"), then it is more likely that ICC-F2 is binding (no side selling of crops). Second, if farmer i is risk averse (i.e., a_i is "large"), she is less likely to side sell her modern inputs; hence, (again) it is more likely that ICC-F2 binds. But if the trader supplies a large quantity of modern inputs (x is large), then it is more likely that ICC-F1 binds. To streamline the exposition below, we will initially assume the following condition holds:

A15: *Assume that* $(1-\beta)(1+z_x)\overline{V}(e^{'}) - (1-\beta)(1+h)\overline{V}(e^*) + w(e^*-e') + x - e'\psi - \frac{1}{2}a_i(1-\beta)^2 E(z_x)^2(1+z_x)^2\overline{V}^2(e') \le 0$. *This means ICC-F2 binds.*

If A15 holds, we can use (13) and rewrite the ICC to derive a lower bound for payment R:

$$R \geq r\left((1-\beta)(1+h)\overline{V}(e^*)+\psi e^*\right)+(1-r)\left(w(e^*-\widehat{e}_i)+(1-\beta)\overline{V}(\widehat{e}_i)+\psi e^*-\frac{1}{2}a_i(1-\beta)^2\rho^2\overline{V}^2(\widehat{e}_i)\right). \tag{CF2}$$

Next, turn to the incentive compatibility constraint for the trader. When spot market values are "low," the trader is tempted to renege and not pay $(R-x)$ but, instead, offer the "cheap" spot market price—even if the farmer supplied e^*. The incentive compatibility constraint for the trader reads as follows:

$$\beta(1+l(x))\overline{V}(e^*)-x+\frac{\Pi_T^{BB}(1-r)}{r} \leq (1+l(x))\overline{V}(e^*)-R+\frac{(1-r)\left[\frac{3+l(x)+h}{3}\overline{V}(e^*)-R\right]}{r} \tag{20}$$

where $(1+l(x))\overline{V}$ is the minimum value of the crop. The first term on the LHS captures the immediate gains from defection for the trader, when the value of output is low. The trader may renege by offering only the low spot market price, instead of the agreed price. The term x are inputs provided to the farmer, which cannot be reclaimed (sunk costs for the trader). The third term denotes the net present value of trader payoffs from future trading on the spot market. The right-hand side (RHS) denotes returns to compliance—the sum of the immediate "loss" associated with paying R while the market value of the crop is lower plus the discounted value of relational trading. Using (13) and (6), the ICC-T defines an upper bound for payment R:

$$R \leq r\left((1+\mathrm{l}(x))\overline{V}(e^*)+\psi e^*-\beta(1+\mathrm{l}(x))\overline{V}(e^*)\right)+(1-r)\left(\frac{3+l(x)+h}{3}\overline{V}(e^*)-\beta\overline{V}(\widehat{e})\right). \tag{ICCT}$$

A-priori it is not possible to say which constraint is binding for the farmer, the incentive compatibility constraints for a farmer (ICC-F) or the participation constraints for the farmer (PC-F), nor which constraint is binding for the trader: the incentive compatibility constraints for a trader (ICC-T) or the participation constraints for the trader (PC-T). This depends on parameters.

5 | SOLVING THE RELATIONAL CONTRACTING MODEL

Participation and incentive compatibility constraints define the range where relational contracts are feasible. The combination of the most binding constraints for the farmer and trader matters, with the former defining a minimum payment R and the latter defining the maximum feasible payment.

The participation and incentive compatibility constraints can be displayed in a figure with payment R on the vertical axes, and effort level e^* on the horizontal axes, as in Figure 1 below. For every possible effort level $e^* < T$, one combination of farmer and trader constraints is binding—the "highest" farmer constraint (i.e., the constraint spelling out the minimum R that induces farmer compliance), and the "lowest" trader constraint (i.e., the constraint defining the maximum R that induces trader compliance). Depending on the effort level chosen (and parameters), and assuming that A15 holds, four pairs of constraints are feasible: {ICC-T, ICC-F}, {ICC-T, PC-F}, {PC-T, ICC-F}, and {PC-T, PC-F}.

Consider these constraints in more detail, starting with the farmer constraints. The intercept of the PC-F curve is: $\pi_F^{\mathrm{BB}}-wT$, and its slope is: $\frac{dR}{de^*}=w+\psi$. The intercept of the ICC-F curve equals: $(1-r)\left(\pi_F^{BB}-wT\right)$, and its slope is given by: $\frac{dR}{de^*}=r\left((1-\beta)(1+h)\overline{V}'(e^*)-w\right)+w+\psi$. Because the sign of $\left(\pi_F^{\mathrm{BB}}-wT\right)$ is ambiguous, both constraints may have positive or negative intercepts. But the intercept of ICC-F is necessarily smaller (in absolute terms) than that of PC-F (because $0<r<1$). We also know that the PC-F is positively sloped and linear, and that ICC-F is positively sloped but

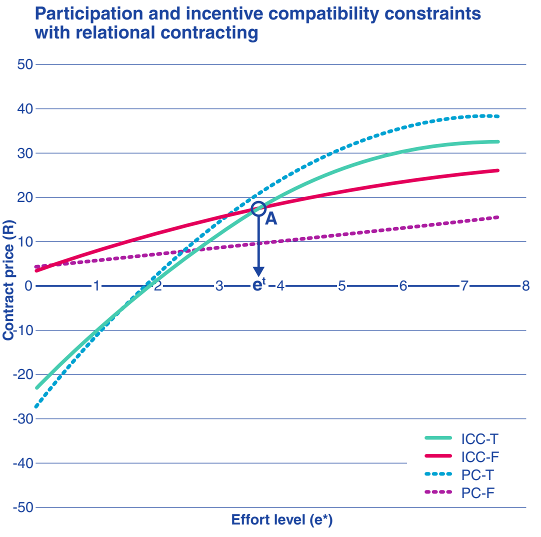

FIGURE 1 Participation and incentive compatibility constraints with relational contracting. Notes: Figure maps participation and incentive compatibility constraints for a trader and a farmer with relational contracting, using the following parameter values: $r = 0.15$; $l = -1.8$; $q = 0.5$; $\beta = 0.5$; $w = 0.5$; $\psi = 1$; $H = 15$; $a = 0.1$; $T = 7.5$. Incentive compatibility constraints for a trader (ICC-T) and a farmer (ICC-F) are the incentive compatibility constraints for the trader and the farmer, respectively. PC-T and PC-F are the participation constraints for the trader and farmer, respectively. Given the parameter values, the feasible space for contracting is enveloped by the ICC-F and the ICC-T, to the right of intersection A.

concave. Because, from (12), for $e \le \hat{e}$, $(1-\beta)\overline{V}'(e) > w$, the slope of ICC-F is unambiguously steeper than the slope of PC-F for all $e \le \hat{e}$. To simplify the exposition, we start by making the following assumption (which we will relax later):

A16: *Assume that* $(1-\beta)(1+h)\overline{V}(e^*) + w(T-e^*) > CE_i = \pi_F^{BB}$. *This implies the ICC-F is more restrictive than the PC-F.*

The LHS of the equation in A16 captures the farmer's temptation to renege or the gains from side-selling when crop prices are high. The RHS captures the expected benefits from being a spot market farmer. If "peak" prices are sufficiently high, then the LHS is greater than the RHS, so the ICC-F binds. In that case, the trader shares part of the surplus to avoid that the farmer side sells on the spot market. This extra payment is an efficiency premium.

Next, turn to the traders. Both the ICC-T and PC-T are concave functions. The intercept of the PC-T is $-\beta\overline{V}(\hat{e})$, and its slope is: $\frac{dR}{de^*} = \overline{V}'(e^*)\left(\frac{3+l(x)+h}{3}\right) + \overline{V}(e^*)l'(x)\frac{\psi}{3} > 0$. The intercept of the $\text{ICC}-\text{T} = -(1-r)\beta\overline{V}(\hat{e})$, and its slope is: $\frac{dR}{de^*} = r\psi + \overline{V}'(e^*)A + \overline{V}(e^*)l'(x)B > 0$ (where $A = \left[\frac{3(1-r\beta)+l(x)(1+2r-3r\beta)+h[1-r]}{3}\right]$ and $B = \frac{\psi(1+2r-3r\beta)}{3}$). Both intercepts are negative. Moreover, these intercepts are both smaller than those of the farmer constraints.[15] Again, we make a simplifying assumption, to be relaxed below, to facilitate the exposition:

A17: *Assume that*: $\beta(1+l(x))\overline{V}(e^*) < x - \frac{-2l(x)+h}{3}\overline{V}(e^*) + \beta\overline{V}(\hat{e})$. *This implies that the ICC-T is more restrictive than the PC-T.*

If "bottom prices" are sufficiently low, then the temptation to renege (and buy cheap) for the trader is so high that the incentive compatibility constraint is binding.

[15]Blouin and Macchiavello (2019) study strategic default between coffee mills and foreign buyers, occurring when market (or production) conditions change sufficiently to place the relational contract outside its self-enforcing range. In our case, if an unexpected output or price shock places the value of production, V, either below lower bound l or above upper bound h, then strategic default occurs (by, respectively, the trader or the farmer). We think of bounds l and h as the expectations of possible future values, shared by farmer and trader. These expectations may be (but need not be) based on experience.

A18: *The trader is the principal who chooses contract terms, and the farmer is the agent.*

A profit-maximizing trader offers a contract located "on the binding constraint" of the farmer. If A16 holds, the ICC-F binds, and the trader offers a payment that leaves the farmer indifferent between complying and side selling when crop values are high. From the trader's perspective, the preferred contract is at the intersection of the lowest iso-profit function and the constraint. The lowest iso-profit function is the combination of (e^*, $R(e^*)$) points with the lowest payment per unit of effort.[16]

Figure 1 provides a graphical exposition of the relational contracting model, assuming that the ICC-F and ICC-T constraints are binding, in line with A16-A17. The figure is based on a "specified" version of the model, simulated in Excel 2016 (Appendix C). To obtain results, we have to specify the production function, as well as the lower limit l of the triangular production function. We use the following specifications in Figure 1 but also the other figures presented below:

$$\overline{V}(e^*) = He^* - e^{*2}, \tag{S1}$$

$$l(x) = l + q \text{ for } x > 0 \quad \text{and} \quad l(x) = l = -h \text{ for } x = 0. \tag{S2}$$

To simulate the model, we set values for: r (discount rate), $h = -l$ (lower and upper limits in triangular function), q (parameter in *l(x)* function), β (bargaining power of the trader), w (wage for off-farm work), ψ (parameter in technical relationship between effort and inputs), H (parameter in production function), a (the coefficient of absolute risk aversion), and T (time endowment).

In Figure 1, and if A15, A16 and A17 hold, then the feasible space for contracting is enveloped by the ICC-F and the ICC-T, to the right of intersection point A. For $e^* < e^t$ it is not possible to write a relational contract as the minimum payment satisfying ICC-F is greater than the maximum payment satisfying ICC-T.

5.1 | Equilibrium outcomes of the relational contracting model

Assume that A16 and A17 hold. The optimal relational contract is summarized in Lemma 1.

Lemma 1. The optimal relational contract chosen by the trader depends on whether the two binding constraints cut zero times, once, or twice:

a. If the constraints of farmer and trader do not intersect, there can be no relationship.
b. If the constraints cross once, then the optimal contract in (e*, R) space is corner solution (T, R[T]).
c. If the constraints cross twice, then the optimal contract in (e^*, R) space is an interior solution (e^{**}, $R[e^{**}]$) where the optimal effort level e^{**} is associated with the intersection of constraints furthest from the origin.

Proof. The intercept of the ICC-T is always below the intercept of the ICC-F. If the slope of the ICC-T is not very steep, relative to the slope of the ICC-F, then the former does not cut the latter for effort values below the endowment T (as in Figure 2).

[16]In contrast, there may be contexts with perfect competition between traders, where farmers may act as first movers and offer a contract. Farmers offer a contract that is either on ICC-T or PC-T, depending on which constraint is binding. The optimal contract occurs where the iso-utility curve of the farmer (a curve with the same slope as PC-F curve) touches the ICC-T or PC-T curve.

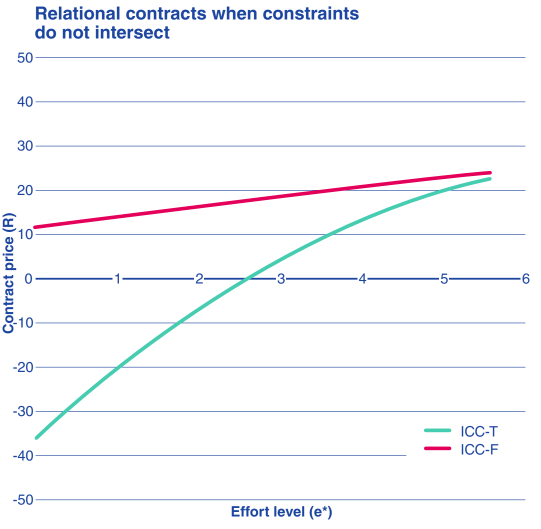

FIGURE 2 Relational contracts when constraints do not intersect. Notes: Figure maps incentive compatibility constraints for a trader (ICC-T) and a farmer (ICC-F) such that the space for contracting is zero. The two incentive compatibility constraints do not cross, which is the case for the following parameter values (as drawn): $r = 0.05$; $l = -1.8$; $q = 0.5$; $\beta = 0.7$; $w = 0.6$; $\psi = 1.2$; $H = 15$; $a = 0.005$; $T = 5.6$.

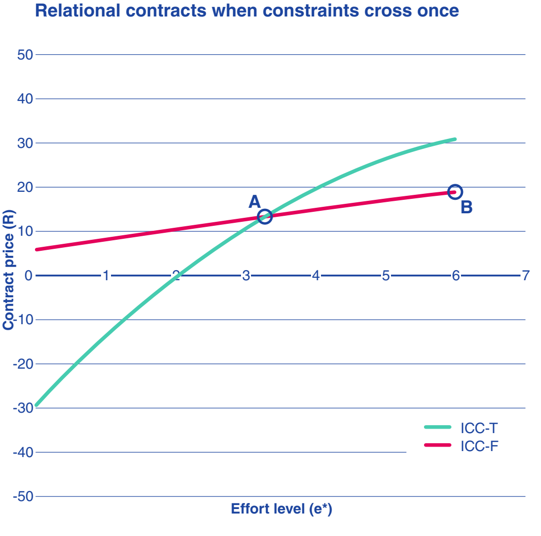

FIGURE 3 Relational contracts when constraints cross once. Notes: Figure maps incentive compatibility constraints for a trader (ICC-T) and a farmer (ICC-F) such that the constraints cross once, which is the case for the following parameter values: $r = 0.05$; $l = -1.8$; $q = 0.5$; $\beta = 0.7$; $w = 0.6$; $\psi = 1.2$; $H = 15$; $a = 0.1$; $T = 6$. In this situation, contracts are on the segment A-B of the ICC-F curve. The optimal contract from the trader's perspective is given by corner B.

The ICC-T curve defines the upper boundary of feasible informal contracts, and the ICC-F defines the lower boundary. Relational contracting is only possible if the two ICCs cross, else the ICC-T is always below the ICC-F and the space for contracting is empty. If the slope of the ICC-T is sufficiently steep, the ICC-T intersects the ICC-F from below, as in Figure 3.

Because traders minimize payments given effort, offered contracts are on the segment A-B of the ICC-F curve. The iso-profit curve has the same slope as the PC-T, and

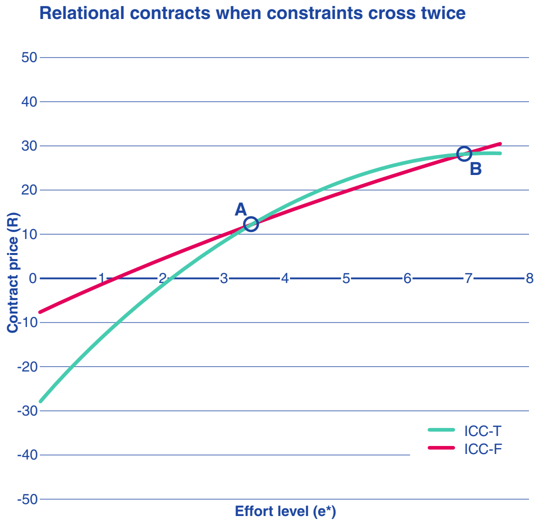

FIGURE 4 Relational contracts when constraints cross twice. Notes: Figure maps incentive compatibility constraints for a trader (ICC-T) and a farmer (ICC-F) such that the constraints cross twice, which is the case for the following parameter values: $r = 0.15$; $l = -1.8$; $q = 0.5$; $\beta = 0.4$; $w = 3$; $\psi = 1.2$; $H = 15$; $a = 0.1$; $T = 7.5$. The second intersection (point B) defines the optimal contract from the trader's perspective.

the lowest iso-profit curve cuts this segment at corner B. Finally, the two incentive compatibility constraints can intersect twice if the ICC-T is (i) sufficiently steep and (ii) "more concave" than the ICC-F. The former cuts the latter from below and then from above. This case is drawn in Figure 4, where the second intersection (point B) now defines the optimal contract from the trader's perspective as this is the point intersecting the lowest iso-profit curve—an interior solution. QED.

Similar outcomes can emerge if different combinations of A15–A17 are relaxed, or when alternative combinations of constraints "bind" (e.g., binding participation constraints or combinations of binding incentive compatibility and participation constraints). The argumentation is nearly identical, and the main results are unaffected.

6 | RISK AVERSION AND RELATIONAL CONTRACTS

A precondition for relational contracting to occur is that the constraints ICC-F and ICC-T intersect at least once. Whether relational contracting is feasible depends, among other things, on the coefficient of absolute risk aversion, parameter a_i, relative to other parameters. Recall that farmers display variation in risk aversion, from risk neutral ($a = 0$) to risk averse ($a = \overline{a}$). Because relational contracting eliminates risk for the farmer, the gains from relational contracting for farmer i vary with risk aversion parameter a_i (the minimum R that avoids side selling is decreasing in risk aversion).

Formally the following holds: risk parameter a affects the CE of spot market farmers, and hence the intercept of the ICC-F curve; $(1-r)\left(\pi_F^{BB} - wT\right)$. More risk averse farmers have a lower CE,[17] so if farmer a is more risk averse than farmer b ($a_a > a_b$), then the ICC-F curve for farmer a is located

[17]This follows from: $\frac{dCE}{da} = -\frac{1}{2}(1-\beta)^2\rho^2\overline{V}' < 0$, where we have used that the first order condition with respect to choice variable $\hat{e}$ is zero for an optimal solution.

below the ICC-F curve for farmer *b*. The intercept of the ICC-T curve, $-(1-r)\beta\overline{V}(\widehat{e})$, is also a function of the farmer's risk aversion parameter, as optimal effort $\widehat{e}$ is lower if farmers are more risk averse. The ICC-T curve for a trader engaging with (more risk-averse) farmer *a* is located above the ICC-T curve for a trader engaging with farmer *b*.[18] The feasible space for contracting is (weakly) larger for more risk averse farmers.

It is possible to identify farmer *j* whose ICC-T and ICC-F just "touch each other" at corner $e^* = T$. In terms of Figure 3, for farmer *j* the ICC-T has shifted down (and the CIC-F has shifted up) to the extent that point A converged with point B. Farmer *j* defines the threshold level for the risk aversion coefficient: $a_j = a^*$ and represents the marginal farmer who can write a relational contract. The optimal contract is a corner solution. Farmers with risk parameter $a_i < a^*$ cannot engage in relational contracting and necessarily become spot market farmers. Farmers who are "not very risk averse" find the income-stabilizing aspect of relational contracting relatively unimportant and are most tempted to side sell their crop when spot prices are high. To induce compliance, these farmers require payments *R* that the trader cannot afford.

Lemma 2. There exists a critical level of risk aversion a* below which the incentive compatibility constraints of farmer and trader no longer intersect. Informal contracts can only be designed for sufficiently risk averse farmers, with $a_i \geq a^*$.

Proof. A decrease in risk aversion *a* below a^* shifts the ICC-F up and the ICC-P down, so that the ICC-F and ICC-T curves do not intersect anymore. This implies that the space for relational contracting has disappeared and the relational equilibrium ceases to exist. QED.

With these building blocks in place, we are ready to evaluate the impact of introducing crop insurance on the use of modern inputs.

6.1 | Insurance and relational contracting

Farmers trading on the spot market seek approaches to smooth consumption. Insurance reduces fluctuations in crop value for farmers, ρ^2. For simplicity, we abstract from all real-life issues that impede the uptake of insurance in real life (e.g., asymmetric information, low trust and limited understanding, and basis risk). This implies brushing under the carpet the issues that constitute the focus of most of the literature on agricultural insurance in low-income countries. Clearly, we do not believe that the formal market for insurance works perfectly, but this "naïve approach" enables focusing on an often-overlooked dimension of insurance—the interaction with pre-existing informal institutions. Importantly, our results do not require that the insurance market is perfect. Our results "go through" as long as traders believe that farmers can turn to the formal insurance market as an alternative risk transfer mechanism.

A19: *Spot market farmers adopt insurance if this improves their utility.*

We ask how the introduction of insurance affects relational contracting and input provision by traders. We demonstrate that insurance shifts both the extensive margin of relational contracting (who can engage in relational contracts, and who cannot?) as well as the intensive margin (how many inputs are provided, conditional on being in a relationship?). The analysis is based on evaluating how insurance affects the intercepts and slopes of binding constraints and, in turn, how this affects the feasible range of relational contracts.

[18]This follows from: $\frac{dCE}{da} = -\frac{1}{2}(1-\beta)^2\rho^2\overline{V}' < 0$, where we have used that the first order condition with respect to choice variable $\widehat{e}$ is zero for an optimal solution.

To address these issues, we must explore how the availability of insurance for smallholders affects the behavior of spot market farmers who cannot access modern inputs (i.e., farmers with $a_i < a^*$). Insurance affects the allocation of their effort between on-farm and off-farm work. Assuming that the adoption of an actuarially fair insurance product attenuates the volatility of the value of production ρ^2, then the relevant comparative static is (Appendix A):

$$\frac{d\hat{e}}{d\rho^2} = \frac{a_i(1-\beta)^2\rho\overline{V}\,\overline{V}'}{V''\left[(1-\beta)-a_i(1-\beta)^2\rho^2\overline{V}\right]-a_i(1-\beta)^2\rho^2\left(\overline{V}'\right)^2}<0. \quad (22)$$

Insurance reduces the riskiness of farming, so after adoption risk averse spot market, farmers will reallocate effort towards farming.

Lemma 3. For non-marginal changes, the uptake of insurance reduces uncertainty for risk averse farmers, crowding in extra on-farm effort. Crop output value increases and the variance of value decreases, which increases the CE of spot market trading. This makes them better off, and all spot market farmers voluntarily adopt actuarially fair insurance.

Proof. Take the first derivative of (8) with respect to the variance: $\frac{dCE}{d\rho^2} = \left((1-\beta)\overline{V}'(\widehat{e}) - w - \frac{1}{2}a_i(1-\beta)^2\rho^2\overline{V}\overline{V}'\right)\frac{d\widehat{e}}{d\rho^2} - \frac{1}{2}a_i(1-\beta)^2\overline{V}^2 = -\frac{1}{2}a_i(1-\beta)^2\overline{V}^2 < 0.$ The term between brackets is the first-order condition for choice variable $\widehat{e}$, and equal to 0 for an optimum solution. For non-marginal changes, the CE increases because income increases and the variance decreases. If A19 holds, they should adopt insurance. QED.

Below we reconsider the implications of introducing insurance for the three familiar cases discussed above: (i) outcomes where the ICC-F and ICC-T do not intersect (as in Figure 2), (ii) outcomes where they intersect once (from below, as in Figure 3), and (ii) outcomes where the ICC-F is "sufficiently concave" to intersect the ICC-T twice—first from below and then from above (as in Figure 4).

Case 1. constraints ICC-T and ICC-F do not intersect.

The introduction of insurance (i.e., reducing ρ^2) affects the parameter space supporting relational contracting. In our two-tier market system, where farmers and traders meet either at the spot market or in a relational contract, changes in the spot market affect opportunity costs of relationships. Introducing insurance increases the intercept of the ICC-F curve, so ICC-F shifts up. In addition, the introduction of insurance invites crowding in of on-farm effort, which shifts the intercept of the ICC-T curve downward. The slopes of these constraints are unaffected.[19] If the ICC-T and ICC-F did not intersect before the introduction of insurance, they will certainly not intersect now—the distance between them has grown. Spot market farmers adopting insurance remain spot market farmers.

Case 2. constraints ICC-T and ICC-F intersecting once.

The introduction of insurance (i.e., reducing ρ^2) shifts up the ICC-F and shifts down the ICC-T, and leaves the slopes of these curves unaffected. This is graphically illustrated in Figure 5, where

[19]The increase in on-farm effort makes trading on the spot market more profitable for traders, increasing the temptation to renege on the relational contract.

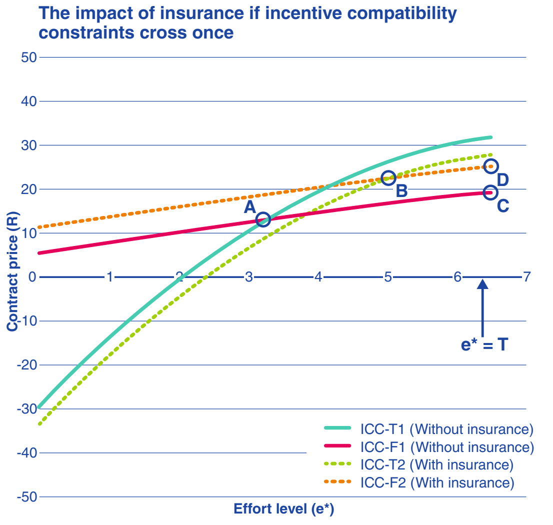

FIGURE 5 The impact of insurance if incentive compatibility constraints cross once. Notes: Figure maps incentive compatibility constraints for a trader and a farmer without insurance (ICC-T1 and ICC-F1, respectively) and with insurance (ICC-T2 and ICC-F2). The parameter values are such that the constraints cross once. The following parameter values are used: $r = 0.05$; $l = -1.8$; $q = 0.5$; $\beta = 0.7$; $w = 0.6$; $\psi = 1.2$; $H = 15$; $a = 0.1$; $T = 6.5$. The feasible space for contracting without insurance is enveloped by ICC-F1 and the ICC-T1, to the right of intersection point A. In this case, offered contracts are on the segment A–C of the ICC-F1 curve. The feasible space for contracting with insurance is enveloped by ICC-F2 and the ICC-T2, to the right of intersection point B. With insurance, contracts are on the segment BD of the ICC-F2 curve. ICC-F, incentive compatibility constraints for a farmer; ICC-T, incentive compatibility constraints for a trader

ICC-F1 and ICC-T1 capture the case where insurance is not available, and ICC-F2 and ICC-T2 capture the new situation after the introduction of insurance. As illustrated, the area where contracting is feasible shrinks from segment AC to segment BD. Indeed, for sufficiently large shifts, the intersection may disappear and relational contracting will come to an end. Our first proposition is as follows.

Proposition 1. Suppose that the incentive compatibility constraints of the contracting parties intersect once. The introduction of insurance reduces volatility of spot market farmers. Trader services (risk absorption and input provision) are available for fewer farmers than before. Insurance impedes the modernization of smallholder farming via contract rationing by traders, who terminate their relationship with farmers who are not very risk averse. The quantity of inputs provided to sufficiently risk averse farmers who retain their contract is unaffected.

Proof. Insurance implies the space for contracting is restricted from AC to BD. For risk averse farmers, the optimal contract remains $e^* = T$ (where the ICC-T intersects the lowest iso-profit curve). These farmers receive a higher price R to avoid side selling. The intensive margin of relational contracting is unaffected: "corner" solution $(T, R[T])$. Outcomes are different for farmers who are not very risk averse. Previously, all farmers i with risk aversion parameter $a_i < a^*$ were excluded from relational contracting where a^* is defined as the level of risk aversion where the old ICC-F just touches the old ICC-T in point C. After introducing insurance, all farmers i with risk-aversion parameter $a_i < a^{**}$ will be excluded from relational contracting, where a^{**} is defined as the level of risk aversion where the new ICC-F (with insurance) just "touches" the new ICC-T in point D, or $(T, R[T])$. The extensive margin of relational contracting thus shifts inward, and fewer farmers are in a relationship with a trader. Recall from A4 that $a_i \in U(0, \overline{a})$ and observe that $0 < a^* < a^{**} < \overline{a}$. Specifically, all farmers with levels of risk aversion $a^* < a_i < a^{**}$ previously received modern inputs from their trader but now lose their relational contract. These farmers can no longer commit to not side selling in years when the value of output is high, because insurance improved their autarky payoffs after reneging. QED.

Proposition 1 is a manifestation of the theory of second best (Lipsey & Lancaster, 1956). Introducing insurance expands the set of markets for smallholders, but this generates ambiguous welfare effects when other markets are missing. We consider a context suffering from multiple market failures: third-party enforcement of contracts is costly, so informal arrangements have to be self-enforcing. Moreover, the markets for credit fails, hence modern inputs are unavailable for smallholders. Introducing insurance in this context implies undermining informal (second-best) institutions without addressing the remaining constraints on credit markets. Inadvertently the space for modernization is contracted.

The same analysis of how intercepts and slopes are affected by the introduction of insurance can be done for the alternative combinations of incentive compatibility and participation constraints. These are the cases when A16 and A17 do not hold. Results are summarized in Table 1. The qualitative nature of the results is robust across the six possible cases.

Case 3. constraints intersecting twice.

Next consider the case where the trader's constraint intersects the farmer's constraint twice–from below and above, as in Figure 4. As before, we first consider the case where A15, A16, and A17 hold (alternative configurations are explored later). The space of feasible relational contracting is on the

TABLE 1 Insurance and modernization: The corner solution

		Trader's participation constraint binds PC-T	**Trader's incentive compatibility constraint binds ICC-T**
Farmer's participation constraint binds PC-F	Extensive margin relational contracting	Shifts inward, fewer farmers are in a relation	Shifts inward, fewer farmers are in a relation
	Intensive margin relational contracting	Unaffected	Unaffected
Farmer's incentive compatibility constraint binds ICC-F1	Extensive margin relational contracting	Shifts inward, fewer farmers are in a relation	Shifts inward, fewer farmers are in a relation
	Intensive margin relational contracting	Unaffected	Unaffected
Farmer's incentive compatibility constraint binds ICC-F2	Extensive margin relational contracting	Shifts inward, fewer farmers are in a relation	Shifts inward, fewer farmers are in a relation
	Intensive margin relational contracting	Unaffected	Unaffected

Abbreviations: ICC-F, incentive compatibility constraints for a farmer; ICC-T, incentive compatibility constraints for a trader; PC-F, participation constraints for the farmer; PC-T, participation constraints for the trader.

segment AB, and the optimal contract is in point B. Define the optimal contract as $(\tilde{e},\ R(\tilde{e}))$. Corner solution $(T, R[T])$ cannot be sustained because traders will renege when crop prices are low. Farmers in a relational contract engage in a portfolio of activities—dividing their time between contract production and off-farm labor.

Proposition 2. If the incentive compatibility constraint of the trader cuts the incentive compatibility constraint of the farmer twice, then the introduction of insurance implies that fewer farmers will be included in relational contracting by traders. Moreover, included farmers will receive fewer inputs (and will work fewer hours on their farm) after the introduction of insurance.

Proof. As before, stabilizing the returns to spot market farming shifts up the ICC-F and shifts down the ICC-T, shrinking the space for relational contracting: Point A moves to the right and Point B moves to the left. The optimal contract $(\tilde{e}, R(\tilde{e}))$ for a risk averse farmer shifts to the left along the ICC-F curve. The intensive margin shifts inward for risk averse farmers remaining in a relationship; e^* goes down, and these farmers receive less inputs.[20] Some not very risk averse farmers will be excluded from relational contracting. Moving from more to less risk averse farmers, intersection points A and B converge, then merge (a bifurcation point), and eventually disappear. The bifurcation point defines the threshold level of risk aversion for contracting to occur. Denote the threshold risk aversion level where the ICC-T and ICC-F "touch" by $a_i = a^{***}$. All farmers with $a^* < a_i < a^{***}$ previously received modern inputs from their trader, but now are excluded from relational contracting. QED.

The same analysis can be done for alternative combinations of constraints. Results are summarized in Table 2. The unambiguous outcome is that fewer farmers receive inputs, and those who continue to receive inputs will receive less of them.

6.2 | Yield-enhancing modern inputs

Next consider the case where the trader supplies yield-enhancing inputs that increase crop value in good years. Risk-reducing and yield-enhancing inputs both increase expected crop value, but the former lowers the crop value's variance, and the latter increases it. This distinction, however, is unimportant for the comparative static results with respect to insurance. This is evident from Appendix B, where we derive the relevant participation and incentive compatibility constraints, and show that in a qualitative sense these are unaffected (i.e., concave, upward sloping constraints, intersecting zero times, once or twice).

Proposition 3. Assume that inputs are yield enhancing. Then, under A1–A18, insurance shifts the intensive and extensive margins of yield-enhancing inputs inward (same result as for risk-reducing inputs). Yield-enhancing inputs accentuate the risk of side selling by the farmer, so the efficiency premium paid by the trader increases.

Proof. As before, feasible space for contracting is below the binding trader constraint and above the binding farmer constraint, and the optimal solution is where the farmer constraint intersects the iso-profit curve. As before, the introduction of insurance shifts intensive and extensive margins inward. Levels of input provision will differ across types.

[20]The increase in on-farm effort makes trading on the spot market more profitable for traders, increasing the temptation to renege on the relational contract.

TABLE 2 Insurance and modernization: The interior solution

		Trader's participation constraint binds PC-T	Trader's incentive compatibility constraint binds ICC-T
Farmer's participation constraint binds PC-F	Extensive margin relational contracting	Shifts inward, fewer farmers are in a relation	Shifts inward, fewer farmers are in a relation
	Intensive margin relational contracting	Shifts inward, farmers in a relationship receive fewer inputs	Shifts inward, farmers in a relationship receive fewer inputs
Farmer's incentive compatibility constraint binds ICC-F1	Extensive margin relational contracting	Shifts inward, fewer farmers are in a relation	Shifts inward, fewer farmers are in a relation
	Intensive margin relational contracting	Shifts inward, farmers in a relationship receive fewer inputs	Shifts inward, farmers in a relationship receive fewer inputs
Farmer's incentive compatibility constraint binds ICC-F2	Extensive margin relational contracting	Shifts inward, fewer farmers are in a relation	Shifts inward, fewer farmers are in a relation
	Intensive margin relational contracting	Shifts inward, farmers in a relationship receive fewer inputs	Shifts inward, farmers in a relationship receive fewer inputs

Abbreviations: ICC-F, incentive compatibility constraints for a farmer; ICC-T, incentive compatibility constraints for a trader; PC-F, participation constraints for the farmer; PC-T, participation constraints for the trader.

The provision of risk-reducing inputs increases $l(x)$, which mitigates the risk of default by the trader (reneging by traders is less attractive in bad states). In contrast, the provision of yield enhancing inputs increases $h(x)$, which accentuates the risk of default by the farmer (making side selling more attractive in good states). This is evident from observing the ICC-F. This curve's intercept is unaffected, but the slope of the ICC-F varies with the type of input provided. Specifically, the slope of ICC-F curve for the case of yield-enhancing inputs is:

$$\frac{dR}{de^*} = r\Big((1-\beta)(1+h)\overline{V}'(e^*) - w + h'\omega\overline{V}(e^*)\Big) + w + \psi, \tag{23}$$

which is steeper than the slope of the ICC-F for risk-reducing inputs. To induce compliance by farmers, traders should write more generous contracts—increasing R per unit of contracted effort, e^*. QED.

7 | DISCUSSION AND CONCLUSIONS

We explore how the introduction of insurance affects the modernization of farming in a context where input markets are imperfect and formal contracting is prohibitively expensive. We develop a two-tiered model where a subset of farmers operate on spot markets and the rest are involved in relational contracts where they receive modern inputs from traders. In addition, those involved in relational contracts are fully insured by traders, but farmers operating on spot markets are exposed to risk. Introducing formal insurance in such a context directly reduces risk exposure of farmers operating on spot markets but also indirectly has an impact on relational contracting. The intuition is that, because operating on spot markets is essentially the outside option for relational contracting, both the participation and incentive compatibility constraints needed to sustain relational contracts are shifted. Because insurance generally improves spot market farmer welfare, this puts pressure on the constraints that make it more difficult to transfer modern inputs via relational contracts. Fewer farmers receive modern inputs from traders, and those farmers receiving inputs will receive smaller quantities. In other words, insurance slows down the modernization of smallholder farming.

We close with three concluding remarks. First, although insurance impedes the modernization of farming, adopting farmers are still better off (else they would not adopt). Stabilization of crop income increases the CE for spot market farmers and enables them to re-allocate effort toward the activity with the highest expected marginal returns (crop production).[21] Smallholders with a relational contract may also benefit because traders offer a higher efficiency premium to prevent side selling—they receive a more generous payment per unit of contracted effort (but in some cases they receive fewer inputs). However, not all market parties gain. Relational traders lose part of their surplus as they have to pay a higher efficiency premium. Moreover, as the extensive margin shifts inward, some farmers are excluded from relational contracting and lose their efficiency premium. Insurance therefore has distributional consequences among smallholders (depending on their level of risk aversion) and between smallholders and traders.

Second, because the welfare implications from formal insurance are complex and work through multiple channels, it is not evident that agricultural insurance should be subsidized. The main approach to promoting the uptake of (index) insurance among smallholder farmers is by heavily subsidizing premiums (e.g., Cole & Xiong, 2017). If agricultural insurance "crowds out" relational contracting because it is a superior risk transfer mechanism, then one could argue that this is simply the result of competitive market forces. However, if insurance crowds out relational contracting because of premium subsidies, then the welfare implications are not so clearcut. Our results suggest that the provision of premium subsidies to smallholders should be rethought and implemented with much greater attention for pre-existing informal institutions. Importantly, this insight extends beyond the case of formal insurance and relational contracting for input provision. Similar results may be obtained for other risk-transfer mechanisms and other types of relational contracting involving smallholders and local traders.

Third, our finding that insurance availability may retard the growth of agricultural modernization in Africa is dependent on relational contracting being the only source of improved inputs. However, this should not be misconstrued as an argument against insurance. Although insurance appears as the "culprit" in our story, another perspective is simply that smallholder farmers do not need less insurance but rather that they need better access to improved inputs. Indeed, a developing market for insurance may provide an impetus to development of the market for modern inputs, for example by increasing demand for inputs. In the setting of a richer model with multiple crops and production modalities, insurance affects ex-ante risk behavior of spot market farmers and raises (expected) incomes. This could generate savings that some farmers may use to access input markets—enabling agro-dealers to expand. Ultimately, the relationship between insurance and modernization of agriculture is an empirical question, with outcomes depending on the interplay between formal and informal markets.

CONFLICT OF INTEREST

none.

REFERENCES

Andrabi, T., M. Ghatak, and A. Khwaja. 2006. "Subcontractors for Tractors: Theory and Evidence on Flexible Specialization, Supplier Selection and Contracting." *Journal of Development Economics* 79(2): 273–302.

Antras, P., and A. Costinot. 2011. "Intermediated Trade." *Quarterly Journal of Economics* 126: 1319–74.

[21]Traders active on the spot market may gain as spot market farmers supply greater quantities (due to the re-allocation of labor).

Aoki, M. 2001. *Toward a Comparative Institutional Analysis*. Hong Kong: MIT Press.
Ashour, M., D. Gilligan, J. Blumer Hoel, and N. Karachiwalla. 2019. "Do Beliefs about Herbicide Quality Correspond with Actual Quality in Local Markets? Evidence from Uganda." *Journal of Development Studies* 55(6): 1285–306.
Back, K. 2016. *Asset Pricing and Portfolio Choice Theory*, Second ed. New York, NY: Oxford University Press.
Banerjee, A., and E. Duflo. 2000. "Reputation Effects and the Limits of Contracting: A Study of the Indian Software Industry." *Quarterly Journal of Economics* 117(1): 39–84.
Banerjee, A., and K. Munshi. 2004. "How Efficiently is Capital Allocated? Evidence from the Knitted Garment Industry in Tirupur." *Review of Economic Studies* 71(1): 19–42.
Bardhan, P., D. Mookherjee, and M. Tsumagari. 2013. "Middlemen Margins and Globalization." *American Economic Journal: Microeconomics* 5(4): 81–119.
Bardhan, P. 1983. "Labor-Tying in a Poor Agrarian Economy: A Theoretical and Empirical Analysis." *Quarterly Journal of Economics* 98(3): 501–14.
Binswanger, H., and M. Rosenzweig. 1986. "Behavioural and Material Determinants of Production Relations in Agriculture." *Journal of Development Studies* 22: 503–39.
Blouin, A., and R. Macchiavello. 2019. "Strategic Default in the International Coffee Market." *Quarterly Journal of Economics* 134(2): 895–951.
Bold, T., K. Kaizi, J. Svensson, and D. Yanagizawa-Drott. 2017. "Lemon Technologies and Adoption: Measurement, Theory, and Evidence from Agricultural Markets in Uganda." *Quarterly Journal of Economics* 132: 1065–100.
Boucher, S., M. Carter, and C. Guirkinger. 2008. "Risk Rationing and Wealth Effects in Credit Markets: Theory and Implications for Agricultural Development." *American Journal of Agricultural Economics* 90: 409–23.
Cai, J. 2016. "The Impact of Insurance Provision on Household Production and Financial Decisions." *American Economic Journal: Economic Policy* 8: 44–82.
Carter, M., A. de Janvry, E. Sadoulet, and A. Sarris. 2017. "Index Insurance for Developing Country Agriculture: A Reassessment." *Annual Review of Resource Economics* 9: 421–38.
Casaburi, L., and R. Machiavello. 2019. "Demand and Supply of Infrequent Payments as a Commitment Device: Evidence from Kenya." *American Economic Review* 109(2): 523–55.
Christiaensen, L., L. Demery, and J. Kuhl. 2010. *"The (Evolving) Role of Agriculture in Poverty Reduction: An Empirical Perspective." (Working Paper)*. Helsinki, Finland: UNU-WIDER.
Cole, S., and W. Xiong. 2017. "Agricultural Insurance and Economic Development." *Annual Review of Economics* 9: 235–62.
Dercon, S., and D. Gollin. 2014. "Agriculture in African Development: Theories and Strategies." *Annual Review of Resource Economics* 6: 471–92.
Do Nascimento Miguel, J. 2022. *Returns to Quality in Rural Agricultural Markets: Evidence from Wheat Markets in Ethiopia*. Washington DC: IFPRI Discussion Paper 02101.
Duflo, E., M. Kremer, and J. Robinson. 2011. "Nudging Farmers to Use Fertilizer: Theory and Experimental Evidence from Kenya." *American Economic Review* 101: 2350–90.
Dupas, P., and J. Robinson. 2013. "Why Don't the Poor Save More? Evidence from Health Savings Experiments." *American Economic Review* 103: 1138–71.
Emerick, K., A. de Janvry, E. Sadoulet, and M. Dar. 2016. "Technological Innovations, Downside Risk and the Modernization of Agriculture." *American Economic Review* 106: 1537–61.
Fafchamps, M. 2004. *Market Institutions and Sub-Saharan Africa: Theory and Evidence*. Cambridge, MA: MIT Press.
Fafchamps, M. 2010. "Spontaneous Markets, Networks, and Social Capital: Lessons from Africa." In *Institutional Microconomics of Development*, edited by T. Besley and R. Jayaraman, 41–88. Cambridge, MA: MIT Press.
Fischer, M., T. Abate, R. Lunduka, W. Asnake, Y. Alemayehu, and R. Madulu. 2015. "Drought Tolerant Maize for Farmer Adaptation to Drought in Sub Saharan Africa: Determinants of Adoption in Eastern and Southern Africa." *Climatic Change* 133: 283–99.
Foster, A., and M. Rosenzweig. 2010. "Microeconomics of Technology Adoption." *Annual Review of Economics* 2: 395–424.
Gianessi, L., and A. Williams. 2011. "Overlooking the Obvious: The Opportunity for Herbicides in Africa." *Outlooks on Pest Management* 22: 211–5.
Haggblade, S., P. Hazell, and P. Dorosh. 2007. "Sectoral Growth Linkages between Agriculture and the Rural Nonfarm Economy." In *Transforming the Rural Nonfarm Economy: Opportunities and Threats in the Developing World* (pp. 141–182), edited by S. Haggblade, P. Hazell, and T. Reardon. Baltimore: Johns Hopkins University Press.
Janzen, S., and M. Carter. 2019. "After the Drought: The Impact of Microinsurance on Consumption Smoothing and Asset Protection." *American Journal of Agricultural Economics* 101: 651–71.
Hill, R., N. Kumar, N. Magnan, S. Makhija, F. de Nicola, D. Spielman, and P. Ward. 2019. "Ex Ante and Ex Post Effects of Hybrid Index Insurance in Bangladesh." *Journal of Development Economics* 136: 1–17.
Karlan, D., R. Osei, I. Osei-Akoto, and C. Udry. 2014. "Agricultural Decisions after Relaxing Risk and Credit Constraints." *Quarterly Journal of Economics* 129: 597–652.
Kuijpers, R., and J. Swinnen. 2016. "Value Chains and Technology Transfer to Agriculture in Developing and Emerging Economies." *American Journal of Agricultural Economics* 85(5): 1403–18.
Levin, J. 2003. "Relational Incentive Contracts." *American Economic Review* 93(3): 835–57.

Ligon, E., and E. Sadoulet. 2007. *Estimating the Effects of Aggregate Agricultural Growth on the Distribution of Expenditures*. Washington DC: World Bank.

Lipsey, R., and K. Lancaster. 1956. "The General Theory of Second Best." *Review of Economic Studies* 24(1): 11–32.

Machiavello, R., and A. Morjaria. 2015. "The Value of Relationships: Evidence from a Supply Shock to Kenyan Rose Exports." *American Economic Review* 105(9): 2911–45.

Machiavello, R., and A. Morjaria. 2021. "Competition and Relational Contracts in the Rwanda Coffee Chain." *Quarterly Journal of Economics* 136(2): 1089–143.

McArthur, J., and G. McCord. 2017. "Fertilizing Growth: Agricultural Inputs and their Effects in Economic Development." *Journal of Development Economics* 127: 133–52.

McMillan, J., and C. Woodruff. 1999. "Interfirm Relationships an Informal Credit in Vietnam." *Quarterly Journal of Economics* 114(4): 1285–320.

Michelson, H., A. Fairbairn, B. Ellison, A. Maertens, and V. Manyong. 2021. "Misperceived Quality: Fertilizer in Tanzania." *Journal of Development Economics* 148: 102579.

Miranda, M., and K. Farrin. 2012. "Index Insurance for Developing Countries." *Applied Economic Perspectives and Policy* 34: 391–427.

Mobarak, A., and M. Rosenzweig. 2013. "Informal Risk Sharing, Index Insurance and Risk Taking in Developing Countries." *American Economic Review Papers and Proceedings* 103: 375–80.

Munshi, K. 2011. "Strength in Numbers: Networks as a Solution to Occupational Traps." *Review of Economic Studies* 78(3): 1069–101.

Sheahan, M., and C. Barrett. 2014. *Understanding the Agricultural Input Landscape in Sub-Saharan Africa: Recent Plot, Household, and Community-Level Evidence*. Working Paper 7014. Washington DC: World Bank Policy Research.

Swinnen, J., K. Deconinck, T. Vandemoortele, and A. Vandeplas. 2015. *Quality Standards, Value Chains, and International Development*. Cambridge: Cambridge University Press.

Walker, T., and J. Ryan. 1990. *Village and Household Economies in India's Semi-Arid Tropics*. Baltimore: Johns Hopkins University Press.

World Bank. 2007. *World Bank Report 2008: Agriculture for Development*. Washington DC: The World Bank.

SUPPORTING INFORMATION

Additional supporting information can be found online in the Supporting Information section at the end of this article.

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