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Introducing quality certification in staple food markets in Sub-Saharan Africa: Four Conditions for Successful Implementation☆,☆☆

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ABSTRACT

Third party quality certification can be used to reduce transaction frictions caused by asymmetric information in value chains. Such certification may help to secure the competitiveness of smallholder farmers in domestic markets for staple crops in Sub-Saharan Africa (SSA) in the face of rising competition with high quality imports. Yet, while frequent in high value export crops, quality certification is still rare for staple crops. To understand why this discrepancy persists, we develop a model with four sufficient conditions for the functionality of certification in a value chain—willingness to pay for quality by downstream agents, upstream competition among traders with pass-through of quality-price premiums to farmers, existence of cost-effective certification, and farmers' capacity to respond to certification by enhancing quality. We show that if these conditions hold, certification should theoretically lead to farmers receiving higher prices for higher quality goods, increasing investment in quality-enhancing inputs, and experiencing welfare gains in response to this quality enhancement. To see if these conditions and results hold in practice, we turn to evidence from a country-level diagnostic survey and from results obtained by others. We find that while certification systems exist in most countries surveyed, evidence of downstream willingness to pay for quality and of price premiums paid to farmers for quality is uneven. However, in cases where quality price premiums do exist, we find evidence that producers respond by enhancing quality. We conclude that policymakers can promote quality certification in staple chains by first ensuring that the four conditions we identify hold.

1. Introduction

As global food value chains increase their reach, more and more imported foods enter consumer markets in developing countries. This includes staple crops, in which domestic producers have historically dominated markets. Given that imported crops are typically produced using modern practices and subject to stringent international quality standards, they tend to be of higher quality than the goods produced for domestic markets. With large fractions of GDP and the labor force in many developing countries in agriculture, it is important to understand what type of value chain upgrading may be possible to help domestic producers compete with imports, especially for staple crops that are widely grown domestically.

One possibility is to encourage the production of better quality products in domestic value chains, especially among smallholder farmers who most often constitute the large majority of producers. This is a challenging proposition given the complexity that characterizes domestic value chains, including in Sub-Saharan Africa (Barrett et al.). Domestic value chains in these contexts are characterized by the presence of numerous intermediaries (such as consignment agents and traders) that play key roles in aggregating the production of many smallholders (so that larger quantities can be transacted with downstream actors), transporting crops from smallholders' farm gates to processors (and other downstream value chain actors), and negotiating trade conditions between the various chain links. Hence even if

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domestic consumers demand higher quality goods, and are willing to pay a price premium for quality, information on quality (which may not be fully observable visually) and the corresponding incentives to deliver quality, must be transferred through each link of these value chains for smallholder farmers to actually want to produce higher quality commodities. Specifically, an asymmetric information problem can arise when farmers and traders attempt to transact. Traders tend to have relatively more information about local market conditions and prices, while farmers tend to have relatively more information about the quality of their own production processes and products. Given this discrepancy, transacting based on the "true" quality of a farmer's crop is generally impossible, as the farmer has an incentive to overstate quality in order to obtain a higher price for the commodity. At the same time traders, who would prefer to pay farmers as little as possible, are aware of this incentive issue and may not believe the farmer's stated quality. Instead, farmers and traders have to transact based on some mutually observed signal of quality (usually the most readily observable information about the commodity), which may or may not be very accurate.

One way of solving this problem is to introduce a third party certification system, which would improve the accuracy of the signal on the basis of which parties must transact. In theory, introduction of certification may incentivize farmers to invest in the quality of their production outputs, as it is more likely they will be awarded a price premium for their efforts. This could significantly improve the welfare of smallholders without necessarily making traders worse off, as traders will only pass through part of the price premium to farmers. Yet despite the theoretical promise of certification in solving asymmetric information issues and inducing quality upgrading, we observe a limited presence of functional quality certification systems for staple foods on domestic markets in Sub-Saharan Africa. While many countries have governmental bodies that provide certification services, these systems in practice tend not to be widely used, especially by smallholder farmers who typically dominate production destined to domestic staple markets.

This presents us with an urgent, policy-relevant puzzle: why do we not see certification used more widely in domestic value chains in the developing world? The short answer is that many of the assumptions that make certification systems promising in theory do not hold in many places throughout the developing world. To establish sufficient conditions that must prevail for quality certification to result in higher price for quality, enhanced crop quality, and welfare gains for responding farmers, we develop a model of farmer response to certification with the following four conditions assumed. First, we assume that some downstream value chain actor (such as a processor or consumers) is indeed willing to pay a price premium for higher quality outputs. Second, we assume that there is sufficient competition among traders, such that the premium downstream actors are willing to pay for quality is at least in part passed through to the smallholder farmer producers. Third, we assume that there exists a certification service for smallholder farmers that is low-cost, effective, and mutually credible, with benefits outweighing costs. And fourth, we assume that there is sufficient capacity among some producers to respond with quality enhancement, allowing for heterogeneity in capacity to respond. Without these four assumptions being satisfied, the theoretical result of a certification system solving the asymmetric information problem between farmers and traders will not necessarily hold.

In order to understand whether there is scope for certification systems to help upgrade output quality in staple crop value chains in SSA, we must verify whether or not these four assumed conditions shown to be sufficient by theory tend to hold in practice. To do this, we combine the results of two exercises: analysis of the results from a diagnostic survey of various agricultural and national standards experts in 20 countries in SSA and of results obtained by others in analyzing certification in value chains. We find that in general these four conditions do not hold in SSA, but that in some contexts throughout the region they do. We also find that in such contexts, there are examples of successful certification schemes, with such schemes tending to induce a farmer quality enhancement response. We thus conclude that for certification schemes to be adopted and for benefits to accrue to smallholder farmers, policymakers should promote the sufficient conditions that will support such a system.

The rest of the paper proceeds as follows. Section 2 provides a background on relevant terms and concepts related to crop quality certification systems. Section 3 develops a theoretical framework to understand how a certification system can transform the interaction between traders and farmers under the four conditions described above. Section 4 briefly describes the diagnostic survey data which we use in the analysis. Section 5 details evidence from the literature and survey results as to whether the sufficient conditions for certification to work in theory are satisfied in practice. Section 6 presents some evidence that certification systems can function in the way suggested by the theoretical model when these conditions hold. Section 7 concludes and Section 8 explains policy implications.

2. Defining quality certification

For the purposes of this article, we define "quality certification" as the adjudication of one or multiple dimensions of a good's quality by an independent party, which then passes on this information to relevant value chain actors. We define a "value chain actor" as any actor involved in production, processing, transportation, marketing, or consumption of the good. It is vital that the agent providing certification be an independent third party (and that value chain actors believe this to be the case), as value chain actors may have incentives to either over- or under-represent various quality attributes (Hatanaka et al., 2005). More specifically, when actors are selling a good to another actor, they may want to over-represent quality to get a higher price, whereas the buyer may want to under-represent quality to pay a lower price.

Suppose that two value chain actors want to transact, and one or both of them cannot observe "true" quality. They then have to transact based on some mutually observable proxy for quality. A certification of that quality dimension can act as a substitute for this proxy; we assume that generally the absolute difference between the "certified" quality and the "true" quality is not greater than between the proxy for quality (in the absence of certification) and "true" quality. This is to say we are assuming that certification generally *does* provide more accurate quality information than that which the parties would have otherwise used to transact.

2.1. Dimensions of quality to certify

The "quality" of a good is a multi-dimensional vector of characteristics of that good, with some dimensions of quality being more "observable" than others. Using an example from Barzel (1982), when buying apples, a buyer might not be able to observe tastiness of an apple before buying it (as apples are experience goods which can only be assessed for taste by consumption after purchase Nelson, 1970), but they may be able to observe the color of the apple, which is possibly correlated with tastiness. Perhaps intuitively, certifications providing information that is not fully or easily observable to downstream supply chain actors may be more useful in terms of making these actors' beliefs about quality closer to the truth. However, even certification of observable characteristics can be useful if actors have unequal market power, by making the contractible proxy of quality closer to the truth.

In practice, certification systems exist for many dimensions of quality, fitting into one or more categories, such as: consumption quality (color, texture, taste, cleanliness), safety (presence of pesticides or other microorganisms), authenticity (guarantee of geographical origin or use of a traditional production methods), or ethical/social concerns regarding the production process (worker conditions, animal conditions, environmental impacts) (Farina and Reardon, 2000). In all of these categories, there can be both process certification and outcome certification.[1] Process certification specifies how a good was produced, processed, and handled along the value chain. For example, organic certification tells other value chain actors that goods were produced without the use of synthetic fertilizers and materials. Generally, such process information is not easily observable to downstream value chain actors in the absence of certification. Outcome certification on the other hand specifies characteristics of a good at a given step of the value chain. An example would be certification that a good contains not more than a certain amount of pesticide residue at the time of being sold to final consumers (Farina and Reardon, 2000). Generally, outcome certification can provide information about quality attributes that are either partially observable or unobservable to downstream value chain actors. This is because, again, even if both parties partially observe quality outcomes they may not be able to transact based on an accurate signal if there are bargaining power differentials.

Important to note is that dimensions of quality that are certified in high value chains destined for export may be quite different than the dimensions of quality that are appropriate for certification in domestic staple value chains in developing countries. Readers may be familiar with the wide array of certification processes and labels associated with smallholders' involvement in value chains for high value crops sold in international markets. Perhaps the most important are the GlobalGAP standards (provided by a private sector institution), with which compliance has become essentially mandatory for any producer in developing countries trying to sell goods to the US or Europe, and even to some supermarket chains in the developing world (Handschuch et al., 2013). GlobalGAP standards ensure safe and hygienic handling of crops, for example limiting the amount of pesticides farmers are allowed to use on a given crop (Asfaw et al., 2010). But beyond this, there is a multitude of quality labels that are familiar to consumers in developed countries such as organic, GM-free, fair trade, cage-free, grass-fed, sustainably sourced, etc. (Messer et al., 2017).

As various studies across contexts have shown that demand for such labels as "organic" tends to increase in income (Chen et al., 2018; Roitner-Schobesberger et al., 2008; Dimitri and Dettmann, 2012), it is unsurprising that in local markets in developing countries, many of these labels that are common in developed countries do not feature prominently. Yet certification of even simple attributes of a good such as "quantity", "size", "cleanliness", "spoilage", or other characteristics associated with taste or nutritional content may garner a premium among local consumers. For instance, local authorities in Senegal provided a weighing and quality grading service in local markets to measure onion quality in terms of density, size, compactness, and likelihood of deterioration. These are characteristics that correlate with taste, cooking quality, and nutritional value of the onion, which local consumers plausibly care about (Bernard et al., 2017).

2.2. Provision of certification

Another relevant question is: who is the third party that provides certification services? Depending on the context, there exist both private and public entities that provide certification services. Reardon et al. (2009) note that the diffusion of minimum public quality standards for grain, and quality and safety standards for meat and dairy, were a common feature in many countries between the 1950s and 1980s (mostly focused on food safety and phytosanitary standards). Beginning in the 1990s, as global markets became more liberalized, the private sector began to play a much more prominent role in certification (Farina and Reardon, 2000). Yet, as Hatanaka et al. (2005) note, public or quasi-public certification and standards entities may still play a role in many countries. Whether the certifier is a public or private sector organization may not matter much in practice to value chain actors, as long as they all perceive the certifier to be independent and objective (Hatanaka et al., 2005). In absence of an official certification service, even a piece of technology that all value chain members can agree is unbiased, such as a ruler or a scale, can serve to provide "certified" and hence contractible information. For example, Abate and Bernard (2017) show farmers how to check whether a trader's scale is unbiased (by having the farmer first step on the scale, as he knows his own weight), which can make the scale into a mutually-trusted quantity certification technology. Regardless of the certifier, it may also be important for there to be a body (which may or may not be governmental) with some regulatory capacity to enforce certifications. Without this, we may expect counterfeiting of certification indicators (such as stickers or bags denoting certification status), eventually rendering such indicators meaningless.

2.3. Market context: Focusing on the link between smallholders and traders

This article focuses on certification interventions through which farmers can certify the quality of their goods before selling them to an intermediary trader. In many developing country crop markets, especially in SSA, traders and various middlemen play a key role in the value chain, often being the first connection between smallholders and local or national markets (Bauer and Yamey, 1954). These traders often assume important market functions such as incurring costs of transportation (Osborne, 2005) and marketing (Fafchamps and Hill, 2005), providing advice and credit to farmers (Casaburi and Reed, 2016), assuming the price and or quality risk inherent in selling agricultural commodities (Dillon and Dambro, 2017), and playing a key aggregation role, in buying goods from many smallholders and selling their combined products to downstream actors. Importantly, as the first point of contact in the value chain for many smallholders, traders often also play the role of quality arbiters. They know that if downstream processors, retailers, and/or consumers will pay more for higher quality goods (and smallholders are aware of this quality premium), smallholders will also want to receive a price premium for producing goods of better quality. However, the trader does not want to "lose out" by paying a high price for goods that are low quality.[2] Hence the uncertainty surrounding quality greatly shapes the prices that traders and producers can transact upon.

However, given that the trader is not the final consumer of these goods, and hence his demand for quality is strictly dependent on downstream value chain actors' demand for quality, we might wonder if some type of quality certification intervention may be more efficient at another link of the value chain. Specifically, certifying at the farmer level may be inefficient for two reasons. First, because smallholders each produce a small quantity, which is then aggregated by traders for the purpose of subsequent transactions, it may be cheaper and more meaningful to certify quality in bulk. Second, in some sense, what the consumer cares about is the final quality of the good. If quality can be improved or may worsen at various steps of the value chain, then quality efforts made at earlier stages may not be representative of final quality. For example, if a smallholder uses very sanitary drying practices for his maize and then sells it to a trader that stores it in unsanitary conditions with other contaminated maize, the smallholder's quality-enhancing effort is wasted. Notably, further-downstream certification is potentially more efficient when the certification in question is an outcome certification. For process certifications, that rely on the

[1] Farina and Reardon (2000) refer to the latter as "output" certifications rather than "outcome".

[2] Of course, given that traders buy from many farmers who may produce varying quality goods, receiving this premium depends on traders being able to discern and keep separated goods of different qualities, and to transact based on unique prices for these different quality supplies with downstream actors.

producer's actions (like organic certification for instance), it may be more efficient to certify at the most upstream link possible, where such process information is easiest to observe.

However, to align with the development goal of increasing smallholder farmer welfare through quality upgrading, certification is likely best done before the farmer sells his produce (unless there are additional asymmetric information problems between more downstream actors in the value chain, which are not currently considered in our theoretical model). If it is done later in the value chain, it is unclear that the premium from this certification will be passed through to farmers, as traders would still be transacting with farmers based on limited information. Hence in order to get the most upstream smallholder farmers to produce quality, it seems reasonable to first focus on the shortest possible segment of the value chain (one link), which is their first contact with traders (and where it is also mechanically the easiest to clearly measure any price premiums paid for smallholder quality inputs).

There is currently little empirical evidence that compares the role of certification at various steps of the value chain. Yet we do know that value chain structures matter in how firms decide to produce quality. For example, Hansman et al. (2020) show that in the Peruvian fishmeal industry when the premium paid downstream for high quality increases, the value chain length tends to decrease, as firms vertically integrate with suppliers. (In their setting, there exists a trade-off for sellers between producing quantity and quality, with both being imperfectly contractible ex-ante. Vertical integration reduces suppliers' outside marketing options, and hence tempers their incentives toward producing quantity at the expense of quality).

3. Theoretical framework

This section proposes a theoretical foundation to our analysis of quality certification in value chains by drawing on the conceptual literature that explains market response to quality in the face of asymmetric information. We present a simple model that predicts how smallholder farmers and traders will react to the introduction of a quality certification mechanism, under the conditions laid out in Section 1.

3.1. Asymmetric information, bargaining power, and quality

Theoretical literature dating back to Akerlof (1970) has contemplated the implications that asymmetric information between a buyer and a seller can have for market transactions. Akerlof models how asymmetric information (where sellers know the quality of a given good and buyers do not) in a market can lead to an unraveling result. The intuition is as follows. If a buyer makes a price offer to a seller, based on the expectation of the quality of a good, the seller will offer the buyer a lower quality good than the bid price offered, as the buyer cannot observe quality. Knowing that the seller will offer a lower quality good, the buyer then instead offers a lower bid price. Yet consequently, the seller will provide a lower quality good at this new lower bid price such that he continues to profit. This process continues to iterate until the price reaches a floor (like zero) at which the transaction will not occur. Hence, knowing that sellers have an incentive to sell low quality cars, buyers are unwilling to buy a car at any price, leading to market failure. However, as Viscusi (1978) notes, this result can be counteracted by introducing a system of quality certification, where firms can invest in quality signaling in order to price discriminate.

Other authors note that in some cases, certification of true quality attributes can be costly to implement, and hence paying to achieve clearer quality information may not be fully efficient or socially optimal (Jovanovic, 1982). For example, Stahl and Strausz (2017) draw a distinction between seller-induced and buyer-induced certification, noting that sellers use certification for signaling, which increases transparency, whereas when buyers demand certification for inspection purposes, it induces sellers to decrease transparency. Additionally, introduction of quality certification may not benefit all producers. For example, Auriol and Schilizzi (2015) show through a survey of the literature and development of a model, that sunken costs of supplier-induced certification can create barriers to entry for developing country producers, leading to more oligopsonistic market structures. Hence they recommend the presence of only a single independent certification body, financed either by consumers/downstream firms or by public subsidies. Similarly, Vandemoortele et al. (2012) develop a model of endogenous introduction of high quality goods into developing country markets where "initial differences in income and capital and transaction costs are shown to affect the emergence of and the size of the high quality economy". Somewhat intuitively, in their model, higher transaction costs along the supply chain serve to constrain the size of the high quality economy, as sourcing from high quality suppliers is more costly. Similarly, their model shows that increases in income (which bolster domestic demand for high quality goods), decreases in capital costs (which lower the cost of producing high quality goods), and decreases in trade costs (which allow firms to access foreign markets more easily) all play a role in the emergence of a high quality sector, and that a sector will not emerge without reaching (minimum or maximum) threshold values in these categories. Hence while in some sense quality certification can have benefits in allowing markets to function, these benefits may not accrue to all market actors.

Finally, while conveying quality information and reducing asymmetric information is an important role of certification, quality certification may also have an important role to play in mitigating the effects of bargaining power differentials between value chain actors. Notably, in the absence of quality certification, even if both buyers and sellers can observe quality reasonably well, they still may not be able to transact based on this quality if parties have differential bargaining power. For example, we might think of a trader trying to convince a smallholder that his goods will not actually fetch as high a price as he thinks in the market, such that the trader might be able to pay the farmer a lower price for his goods. There is some evidence that providing a farmer with market price information might strengthen his bargaining power and increase the price he receives, as it makes market price observable and mutually contractible information for both actors (Courtois and Subervie, 2014; Hildebrandt et al., 2015; Jensen, 2010).[3] It seems possible that certification information works similarly, in that certification makes quality-related information contractible, regardless of whether or not it is observable beforehand. However, other studies of more complex value chains have argued the opposite point; notably Von Schlippenbach and Teichmann (2012) argue that downstream retailers use private quality standards to improve their bargaining position in the intermediate goods market, where stricter differentiation in the few downstream retailers' quality standards decreases the outside options of the many producers trying to market their product towards any one given quality standard. Hence perhaps the way to best sum up the relationship between quality certification and bargaining power is that it depends greatly on the particular market structure and relevant actor.

While there is a significant body of theoretical literature regarding how quality certification affects transactions in various links of the supply chain (for a more thorough review see Dequiedt, 2018), we want to develop a model that is more specifically useful to our context of interest. Hence we want to consider a model of how smallholder farmers and traders interact under a setting of asymmetric information regarding the farmers' production process, and how third-party certification may affect this market exchange.

[3] Yet, it is important to note there are also many examples where simply providing price information to farmers is insufficient. For instance, even in the Hildebrandt et al. article mentioned above, which finds that giving farmers price information increases the prices they receive from traders for yam, there is no similar effect for any of the other four, fairly similar crops studied.

3.2. A simple model of smallholders and traders

Now we develop a simple model that applies these general ideas about the role of quality certification in mitigating the effects of asymmetric information to our specific case of smallholder farmers' interaction with traders, highlighting key assumptions about market conditions that underlie this result. The preliminaries of our model are partially based off on Mitchell (2016), but deviate based on the specific phenomena we aim to demonstrate.

3.2.1. The smallholder farmer's quality production decision

Suppose a risk-neutral farmer i has the option to grow one unit of a crop each season that he will sell to a risk-neutral trader. *We assume (condition 4) that farmers can choose to exert effort to increase the quality (Q) of their output*. Specifically, farmers can produce two possible quality levels high ($Q = H$) for which a farmer would expect to receive price h from the trader, and low ($Q = L$), where the farmer would instead receive price l (with $h, l \geq 0$). In order for the farmer to produce high rather than low quality, the farmer must exert and additional effort cost (c_i), where farmers face heterogeneous effort costs, drawn from the distribution $F(c_i)$. Farmer i can observe c_i, but the trader cannot.

The rational farmer would choose to spend quality cost c_i if it is less than the price benefit of selling a higher quality good. If Q was perfectly observable by both the farmer and the trader, this benefit would just be $h - l$, the difference in sales prices for high and low quality output. However, the key issue here is that the trader cannot perfectly observe Q. Instead, the farmer and trader observe a mutual quality signal s; where $s = Q$ with probability $\rho \in (\frac{1}{2}, 1]$ (and $s \neq Q$ with probability $1 - \rho$). Given that the trader is risk neutral, the farmer will receive an expected price of $\rho h + (1-\rho) l$ when he produces $Q = H$, and an expected price of $\rho l + (1 - \rho) h$ when they produce $Q = L$.

Therefore, a farmer with costs c_i will decide to exert effort in production if the expected value of doing so is greater than the expected value of not doing so. Mathematically, it must be the case that:

$$\rho h + (1 - \rho) l - c_i \geq \rho l + (1 - \rho) h. \tag{1}$$

Simplifying this expression, we discover the set of price premiums $(h - l)$ for which the farmer will choose to exert effort:

$$h - l \geq \frac{c_i}{2\rho - 1} \tag{2}$$

3.2.2. The trader's decision

While the farmer takes prices h and l as given, the trader needs to choose value to set for these prices. *We assume (condition 2) that traders face perfectly competitive markets* and sell their output to a processor who can perfectly observe quality of the crops the trader bought (regardless of the trader's received signal). (We note that in practice, processors may not perfectly observe quality, but often have a more accurate measurement of quality than traders, due to ownership of costly quality-detection capital.) *We assume (condition 1) that the processor is willing to pay the trader a price reflective of quality*, where the trader receives P_H when $Q = H$ and receives P_L when $Q = L$. Therefore, the trader receives an expected price of $\rho P_H + (1 - \rho) P_L$ when $s = H$ (they receive a high quality signal) and an expected price of $\rho P_L + (1 - \rho) P_H$, when $s = L$. The trader also incurs transportation/marketing costs m, regardless of quality type. As the trader faces a perfectly competitive market and is risk neutral, he will pay farmers such that he will make zero profits in expectation. Hence, it must be the case that:

$$h = \rho P_H + (1 - \rho) P_L - m \tag{3}$$

and

$$l = \rho P_L + (1 - \rho) P_H - m \tag{4}$$

3.2.3. Distribution of farmers' decisions

We suppose that all farmers will choose to produce the crop (i.e. l they receive from producing the low quality output is greater than their reservation wage). But which farmers will choose to exert quality-enhancing, but costly effort? Putting Eqs. (2), (3), and (4) together, farmers will choose to exert effort if:

$$(2\rho - 1)^2 [P_H - P_L] \geq c_i \tag{5}$$

So farmers with $c_i \leq (2\rho - 1)^2 [P_H - P_L]$ will exert effort and earn expected payoff: $2\rho(\rho - 1)[P_H - P_L] + P_H - m - c_i$ and farmers with $c_i \geq (2\rho - 1)^2 [P_H - P_L]$ will not exert effort and earn expected payoff: $2\rho(1 - \rho)[P_H - P_L] + P_L - m$. Note that, by construction, the expected payoff for farmers that choose to exert effort will always be greater than or equal to the payoff of them not doing so.

3.2.4. Introducing quality certification

Suppose we introduce some form of third-party quality certification that strengthens the accuracy of the quality signal. *We assume (condition 3) that this quality certification is unbiased and free/of negligible cost for farmers to obtain.*[4] This means that ρ, the probability that the trader receives an accurate signal, which originally took on some pre-certification value (call it ρ_0) increases to a new value we will call ρ' (the certification quality signal). It is now easier for the trader and the farmer to mutually observe the true quality of a good, both when that quality is high or low. How does this change our previous results? We obtain three fundamental outcomes:

Result 1: Prices paid to farmers for high quality signals increase, while prices paid to farmers for low quality signals decrease. Note that traders do not change their standard pricing rules under a certification regime. Referring to the trader's price setting Eqs. (3) and (4), we note that $\frac{\partial h}{\partial \rho} > 0$ and $\frac{\partial l}{\partial \rho} < 0$. Thus it will be true that $h(\rho') > h(\rho_0)$ and $l(\rho') < l(\rho_0)$. That is, under certification, the high quality price paid to farmers increases, and the low quality price decreases.

Intuitively this makes sense, as the more clear the signal becomes, the closer the signal becomes to the true quality, and the closer the price the trader can expect to receive for a good becomes to reality.

Result 2: More farmers will choose to exert effort. As above, farmers choose to exert effort if Eq. (5) holds. As the derivative of the expected benefit of producing high quality: $\frac{\partial}{\partial \rho}(2\rho - 1)^2 [P_H - P_L] > 0$, we know that $(2\rho' - 1)^2 [P_H - P_L] \geq (2\rho_0 - 1)^2 [P_H - P_L]$. Hence any farmer that chooses to exert effort before certification was introduced will still do so. But now farmers with costs c_i such that $(2\rho' - 1)^2 [P_H - P_L] \geq c_i > (2\rho_0 - 1)^2 [P_H - P_L]$ will also choose to exert effort. Farmers with $c_i > (2\rho' - 1)^2 [P_H - P_L]$ will continue not to exert effort.

Result 3: Welfare changes for farmers are mixed; some gain and others lose. Notably, under a certification regime, we see that some farmers adopt certification but not others, and that while the price for a high signal increases, the price for a low signal decreases. Hence it is intuitive that farmers will have mixed overall changes in welfare, with those who exert costly effort generally gaining, and those who do not generally losing. More formally, we separate farmers into three groups (based on their c_i): those who exert effort with and without certification, those who switch into exerting effort when certification is introduced, and those who never exert effort.

Farmers who always exert effort experience a welfare gain. Plugging in the trader's price-setting Eqs. (3) and (4) into the payoffs expression for farmers that exert effort (left side of Eq. (1)), we see that

[4] We note that this is generally not the case in practice, and there is indeed generally a cost associated with obtaining certification. Yet adding this dimension simply adds complexity to the model without changing its general conclusions. Notably, by making certification costless here, we can abstract away from the farmer's decision of whether to certify his crop (as here the choice not to certify a crop reveals to the trader that $Q = L$ with certainty, given all farmers with high quality would choose to certify).

the expected payoff for farmers who exert effort is increasing in the probability of accuracy of the quality signal, ρ. Hence as the original accuracy probability ρ_0 increases to the new accuracy probability ρ', they are more likely to get their deserved premium for their effort (without changing their behavior) and are better off. On the other hand, farmers who never exert effort experience a welfare loss. This can be seen using a similar method of substituting price-setting Eqs. (3) and (4) into the right side of Eq. (1) (the payoff for farmers producing low quality) and noting that this expression is decreasing in signal accuracy probability ρ. Hence these farmers' expected payoffs decrease as ρ_0 increases to ρ'.

Now we consider farmers who did not choose to exert effort before certification but do so after certification. For these farmers, figuring out whether they gain or lose from certification becomes a little less intuitively straightforward. While it may on first look seem like these farmers must gain as they have now switched into producing quality, this may not be the case, as both their expected revenues and costs are changing. So although exerting effort may be the optimal choice for more farmers under the certification scenario, these farmers could still experience a gain or a loss compared to their pre-certification expected payoff. Recall that these marginal farmers have relatively high effort cost c_i, as without certification they did not exert effort. Hence the switch into producing quality causes a discrete jump in terms of their payoff from the trader, but also in terms of their costs. Hence, whether farmers gain or lose depends on the relative magnitudes of these changes. Mathematically, these "switchers" experience a welfare gain when certification is introduced if:

$$c_i < [P_H - P_L][2\rho'(\rho' - 1) + 2\rho_0(\rho_0 - 1)]. \tag{6}$$

Likewise, for farmers where this condition is met with equality, welfare does not change, and farmers where the reverse is true experience a welfare loss. Notice that the right side of Eq. (6) is increasing in both ρ_0 (the original signal accuracy probability) and ρ' (the new signal accuracy probability), meaning that the probability of a switching farmer gaining is increasing in the pre-certification ρ_0 (as this would decrease their pre-certification expected payoff) and increasing in ρ' (as this would increase their post-certification expected payoff).

3.3. Model conclusions

From our simple model of interactions between traders and farmers, we can understand quality certification as enhancing the accuracy of the mutually observable information signal on the basis of which farmers and traders are able to transact. Given that some downstream buyer is willing to pay a premium for quality (condition 1), traders use perfectly competitive pricing behavior (condition 2), and a cheap and credible certification system exists (condition 3), certification causes traders to pay more for a seemingly high quality good and less for a seemingly low quality good (result 1). Hence certification induces more (but likely not all) farmers to engage in quality-enhancing efforts (result 2), given their heterogeneity in quality enhancement capacity (condition 4). Given the possibility of quality-enhancing efforts to effectively produce higher quality, we see that some farmers gain from certification (those that always exert effort and some of the farmers that start exerting effort once certification is implemented) and others lose (those that never exert effort and some that start exerting effort once certification is implemented) (result 3). Note that this "splitting" result in terms of some farmers benefiting from certification while others do not depends on farmers exhibiting some type of heterogeneity–such as differential costs of exerting effort. The model "heterogeneous effort cost" could also be interpreted as any type of heterogeneous constraint faced by farmers that would hinder adoption of a new technology. Some such reasons for heterogeneity in difficulty or costs of adopting quality-enhancing technologies would typically include educational attainments, income levels, capital ownership, soil conditions, credit market constraints, insurance market constraints, and transaction costs. Additionally, it is notable that many smallholder farmers in Sub-Saharan Africa either have negligible sales or are net buyers of staple crops (Mather et al., 2013; Barrett, 2008), and insofar as certification may change the purchase prices of staple crops, this could introduce another source of heterogeneity in welfare effects for smallholder farmers (Jayne et al., 2010). Yet, our model does not provide predictions about equilibrium price changes, and hence we focus here on welfare changes associated with production decisions. In Section 5, we will explore how our model's conclusions hold in empirical settings where our model assumptions regarding markets and certifications generally hold.

4. Data: Diagnostic survey

As part of our analysis of the feasibility of introducing certification services in staple crop value chains in SSA, we conducted a diagnostic survey regarding the existence, implementation, and outcomes of commodity grades and standards (G&S) and certification services in 20 Sub-Saharan African Countries (Burkina Faso, Cameroon, Cote d'Ivoire, DRC, Mali, Ethiopia, Kenya, Mali, Mauritius, Mozambique, Namibia, Niger, Nigeria, Rwanda, Senegal, South Africa, Sudan, Swaziland, Tanzania, and Togo). In each country, one expert was tasked with completing a diagnostic survey regarding the history of, current state of, and predicted future prospects for certification services in their country of expertise. They reported their findings using a standardized survey form we provided.[5] These experts were instructed to consult with other experts (including regulatory officials), to complete their reports.

In the survey, experts in these countries were asked a series of questions about the five most commonly grown crops (by land area) in their country (as given by FAOSTAT, 2018). Notably, in the majority of countries, staple crops dominate this list. In fact, only in Mauritius did the top five crops include only non-staple commercial crops. For the majority of these crops, production is dominated by smallholders; this is the case for about 80% of country-by-crop observations and for about 90% of country-by-crop observations where the crop is identified as a staple crop in that country.[6]

To learn more about staples that are important in Sub-Saharan Africa, we select commonly grown staple crops (identified as one of the mostly commonly grown crops in at least five countries in the sample) as the focus of our analysis. To identify "staple crops" for this exercise, we define a crop to be a staple if the majority of countries in the data for which the crop is in their top five crops report that it is a staple crop. Hence we focus on maize, sorghum, cassava, millet, and rice, which are each identified as staple crops in over 80% of countries where they are a major crop. These crops are mainly grown by smallholder farmers; this is true in 82%, 89%, 100%, 75%, and 100% of country cases, respectively.[7] The countries which report growing each of these crops

[5] Experts to conduct the diagnostic survey in each country were recruited amongst members of the African Growth & Development Policy Modeling Consortium (AGRODEP), the Partnership for Economic Policy network (PEP), and from our own research networks. We are grateful to the detailed information they provided. The list of reporting experts is as follows: Burkina Faso, Omer Combary; Burundi, Jean Ndimubandi, Côte d'Ivoire, Adolphe Mahyao; Democratic republic of Congo, David M. Bugeme; Ethiopia, Kassa T. Alemu; Kenya, Florence Gathoni; Mali, Fadimata Haidara; Mauritius, Krishna Chikhuri; Mozambique, Sergio Ponguane; Namibia, Blessing Chiripanhura; Niger, Saadatou Alkassoum Sangaré; Nigeria, Adeola Olajide; Rwanda, Jean de Dieu Harerimana; Senegal, Samba Mbaye; South Africa, Yonas Bahta; Sudan, Amel Mustafa Mubarak; Swaziland: Joshua Olusegun Ajetomobi; Tanzania: Prudence Lugendo; Togo, Koffi Yovo; Cameroun, Boniface Ngah Epo.

[6] These statistics exclude eight observations with missing values

[7] These statistics exclude one missing observation for sorghum and one for millet.

Table 1
Dimensions of Existing Grade & Standards, by crop and country.

Country	Maize	Sorghum	Cassava	Millet	Rice
Burkina Faso	QS	QS		QS	
Burundi	QSP		QSP		
Cameroon	QS	QS	QS		
Cote D'Ivoire					QSAP
DRC	S		S		S
Ethiopia	QSAP	QSAP			
Kenya	QS				
Mali	QSP	QSP		QSP	QSP
Mauritius					
Mozambique	QS		QS		
Namibia	**				
Niger		**		**	
Nigeria	QS	QS	QS		
Rwanda	QS	QS	QS		
Senegal	QSAP	**		QSAP	QSAP
South Africa	QSAP				
Sudan		QS		QS	
Swaziland	Q				
Tanzania	QS		QS		QS
Togo	SA	SA	SA		
Number of countries with the crop	16	10	8	5	5

The four dimensions are Quality (Q), Safety (S), Authenticity (A), and Production Process (P). The symbol ** indicates that there is no G&S for this crop. A blank entry indicates that this crop in not among the 5 major crops of the country.

can be seen in Table 1.[8] Notably, each country in the data set (except for Mauritius) lists at least one of these five crops as a main crop, and 80% of the countries in the data set report maize as being one of their top five crops.

Generally in order to certify quality, there must be some G&S in which quality can be adjudicated based on. Survey experts were asked whether their country's G&S have regulations regarding the following four domains: its quality (Q), sanitary and phytosanitary safety (S), authenticity in terms of region of origin (A), and production process such as organic and Fair Trade (P). Table 1 shows that there exists a G&S system for 40 of the 44 crop/country combinations; that is 91% of cases. G&S are for Q in 34 of the cases, S in 39, A in 10, and P in 13. Countries like Côte d'Ivoire, Ethiopia, Senegal, and South Africa characterize all four dimensions. G&S exist in 94% of the countries for maize, 80% for sorghum, 100% for cassava, 80% for millet, and 100% for rice. Hence we note that formally, G&S systems are widely prevalent to characterize quality and safety. This allows for the possibility of the existence of certification systems that evaluate various crops in terms of a country's G&S, which we will discuss in later sections.

5. Evidence on the sufficient conditions for certification

In this section, we consider the evidence on whether the sufficient conditions for certification to succeed seem to hold in SSA and more generally throughout the developing world. To do this, we use evidence from the diagnostic survey and from results obtained by others in analyzing certification in value chains.

5.1. Evidence on downstream willingness to pay for quality

We first ask whether there is evidence that consumers or other downstream market actors are willing to pay a premium for quality in agri-food value chains. The answer to this question is somewhat mixed. Bai (2018), who considers the case of laser-cut quality labels in Chinese watermelon markets, suggests that the answer is yes. In this study, Bai notes that while watermelon retailers in local markets in Shijiazhuang buy their goods from a wholesaler, they usually have a better sense of the unobservable quality of taste than their buyers do. Specifically, these retailers can use less obvious observable characteristics, such as color of the stripes, sound of knocking, and curliness of the veins to reasonably accurately predict taste (which Bai validates experimentally). Yet despite this, many of these retailers do not sort melons by quality or demand a premium for better melons. The author hypothesizes that this is either due to consumers having a low willingness to pay for quality or not trusting quality signals from sellers. Hence Bai has 60 retailers agree to differentiate piles of better and worse quality melons for a two-week period. Then some retailers are given a quality certifying technology–either a "high quality" sticker (which is often counter-fitted and hence may be a "contaminated" quality signal) or a novel laser-cut printed label (which is likely "uncontaminated"). The study finds that retailers were indeed able to sell the laser-cut labeled watermelons to consumers at a higher price, and their profits increased by 30% to 40%. Hence, it does seem in this context that consumers exhibit a demand for quality and are willing to pay a premium for it.

Other sets of consumer experiments in Vietnam and China have also demonstrated cases of consumers being willing to pay a premium for higher quality goods. My et al. (2018) find, using a between-subject Becker–Degroot–Marschak mechanism design, that Vietnamese consumers are willing to pay 9% more for rice marked with the "VietGAP" sustainability label, compared to unlabeled rice. Similarly, through an experiment with multiple hypothetical purchase decision choices, Liu et al. (2019) show that food traceability information increases Chinese supermarket consumers' willingness to pay for Fuji apples. Yet this increased willingness to pay for traceability is not seen in all goods; Wang et al. (2019) find that Chinese supermarket consumers do not exhibit increased willingness to pay for milk powder with traceability information in similar choice experiments, and that the milk powder's country of origin plays a more significant role in consumer purchase decisions.

Hoffmann and Gatobu (2014) show in a Sub-Saharan Africa context that consumers exhibit willingness to pay for higher quality, including for a staple good. Specifically, they consider farmers' willingness to pay for maize in a framed field experiment in Western Kenya. The researchers invited farmers to a lab, and used a sealed-bid second price auction mechanism to determine a farmer's willingness to pay for: maize the farmers themselves had produced (and had been purchased by the experimenters previously), maize purchased from a local trader, and maize purchased by the experimenters from a different farmer. Among maize purchased from the trader, the experimenters varied how it was sold as follows: as-is from the market, sorted (with discolored and broken kernels, insects, and debris removed), certified to be below the allowable limit of aflatoxins (a harmful toxin that can be present if maize is not dried properly and can cause deleterious health effects), both sorted and aflatoxin certified, and sorted along with the opportunity for participants to taste a bit of porridge made by the maize before bidding. The researchers found that farmers displayed the highest willingness to pay for the maize they themselves had produced, at an average price of about 42.14 Ksh/kg, compared to 27.20 Ksh/kg for the as-is maize from the market. Yet, the sorting and certifications increased the willingness to pay compared to the "as-is" maize substantially; having been both sorted and certified garnered an average bid of 35.61 Ksh/kg and being able to taste the porridge from that maize brought the average bid up to 37.11 Ksh/kg. Hence it does seem that even on staple crop markets, consumers have some willingness to pay for improved quality in dimensions such as cleanliness, safety, and taste.

Yet on the other hand, using a separate survey of 1500 customers buying maize at a small-scale hammer mill in Eastern Kenya, Hoffmann et al. (2013) find that while the price respondents pay for maize

[8] Some countries note growing more broad categories that likely include the aforementioned crops such as "cereals" and "millet/sorghum". We do not consider these in this analysis, as we cannot be sure as to which crops they refer.

does depend on observable qualities like kernel discoloration, after controlling for this, aflatoxin level (which is more difficult to observe) does not have a statistically significant impact on price paid. They also show that this is not because these buyers are unaware of aflatoxins or their danger; 94% of respondents reported sorting grains before milling, with 74% percent of those citing health reasons for doing so. The authors also show that consumers use maize with higher aflatoxin levels differently; they are less likely to use it for maize flour or food, and more likely to use it for alcoholic beverages, livestock feed, or sale. The authors conclude that consumers observe attributes that are correlated with aflatoxin levels upon careful inspection, and perhaps base their use of the maize on this information. On the other hand, in the further downstream market for processed maize flour, follow up work by Hoffmann and Moser (2017), using data from more than 900 maize flour samples representing 23 distinct brands in eastern and central Kenya, shows a strong negative correlation between price and aflatoxin contamination at the brand level. Hence perhaps Kenyan households who purchase maize flour are indeed willing to pay a premium for more sanitary goods.

Fafchamps et al. (2008) present similar mixed findings on willingness to pay based on the observability of quality attributes in five staple and non-staple crop markets (mango, tomato, potato, maize, and tumeric) from four states in India. Through surveying farmers, traders, processors, and buyers, the authors show evidence that while information regarding observable quality attributes (like size and color) is passed throughout the value chain and generally rewarded with a premium, much information about unobservable attributes is not. Specifically, they find that information regarding pesticide and fertilizer application, post-harvest pesticide treatment, or the origin of irrigation water used is generally not passed down the value chain, which could potentially cause a safety risk to consumers. Given the lack of pass-through of this information, unsurprisingly, mitigating sanitary behaviors are generally unrewarded and growers lack knowledge about such practices. Hence they do not find clear evidence that Indian consumers are willing to pay for sanitary quality attributes. The willingness to pay for various quality attributes in developing country markets thus likely depends a lot on context, and especially on the demand consumers have for different quality attributes.

Expert reports from the Diagnostic Survey note that lack of consumer demand for quality or certified products may limit farmers' use of certification services. For instance, the survey report from Kenya notes that "...these services are currently inaccessible to cereals and pulses small scale farmers. This inaccessibility could be attributed to a number of factors; (1) small scale producers normally sell their produce in unregulated local markets where both consumers and traders are unaware of existence of such standards..". Similarly, the surveyed expert from Mali notes that local consumers have little regard for the quality of cereals, and hence mainly consider volume when setting purchasing prices. In such contexts, we may not expect farmers to take up certification unless a local demand for quality of staples is first stimulated. Moreover, evidence as to whether condition one holds is mixed, and may also vary greatly by crop and setting.

5.2. Evidence on market competitiveness

We then ask whether there is sufficient competition for traders to pass any quality premium they receive from a buyer on to farmers. Dillon and Dambro (2017) note that while it is often claimed that crop markets in Sub-Saharan Africa lack competition, there is little empirical evidence supporting this point, and the evidence that does exist generally suggests that markets are competitive. Interestingly, we still see some compelling evidence in the literature of incomplete price pass-through, suggesting some lack of competition in these markets. For instance, using a randomized controlled trial in Kenya, Bergquist and Dinerstein (2020) tries to understand how much of a randomly assigned per-unit subsidy to maize traders gets passed through to farmers. She finds that the rate of pass-through is less than the 100% expected in a perfectly competitive model. Additionally, Osborne (2005) shows that traders may pay different prices to different farmers, and that competitiveness of the setting may play a role in this. She shows that imperfect competition in a typical remote source market for wheat in Ethiopia drives prices paid to traders down by about 3%, whereas in a more central (and competitive) market, there is no conclusive evidence of imperfect competition driving down prices. Osborne notes that one reason for this differential may be that farmers in the more central market tend to have better price information. Hence it may be the case that when more information (such as price or quality information) is available to both farmers and traders, farmers receive higher prices.

Yet even if there is no evidence of full pass-through in many settings, we do see evidence of some pass-through in various domestic developing country markets, in that we see higher prices being paid to farmers who produce higher quality goods. For example, though it does not apply to all quality attributes, Fafchamps et al. (2008) note that Indian growers receive premiums for observable quality attributes like size and color. A similar result is found by Abate and Bernard (2017). They study smallholder wheat producers in the Oromia and Amhara regions of Ethiopia, and specifically how these farmers can utilize simple methods and technologies to display a more accurate quality signal regarding their own wheat's quality. In randomly selected villages, the researchers introduced certification technologies; they taught farmers how to measure hectoliter test-weight (a measure of the flour extraction rate) with locally available instruments and how to produce higher quality wheat (for example by applying nitrogen fertilizer). In some of the randomly selected treatment villages, farmers were also given a video training about the bargaining benefits of collective farming, and taught how to bargain for a fair price (by consulting with more than one trader before selling their product, and by checking to see if traders' scales are fair by weighing themselves first). They indeed show that treated farmers (in both groups) that produce higher quality wheat receive higher prices from traders, and are less likely to want to market their wheat cooperatively (where it will likely get mixed in with wheat of a lower quality and earn a lower price). Similarly, Bernard et al. (2017) also find evidence of price pass-through, in considering the introduction of onion quality certification booths through an experimental program in markets in Senegal. The intervention involved introducing scales (such that farmers would have an incentive to produce more dense and nutritious, rather than simply "large" onions) and a quality grading system (which characterized the density, size, and spoilage of the onions). The authors used natural variation in when certification booths began to operate in various markets to show that once certification booths were introduced, there was a discrete increase in the prices paid to farmers for high quality onions.

We see complementary evidence of price being passed through to smallholders participating in high-value crop chains, where goods are destined for export. For example, Macchiavello and Miquel-Florensa (2017) explore the smallholder provision of premium grade coffee in Colombia to a large foreign buyer. They exploit the staggered roll-out of the "Quality Sustainability Program" by region, and estimate an intent-to-treat effect of the program using a difference-in-differences approach. While farmers who participate in the Quality Sustainability Program and produce premium-grade quality are promised a 10% price premium for their coffee, farmers actually sell their goods to an intermediary local cooperative rather than directly to the buyer. Yet the authors' estimates show that despite the presence of this intermediary, program farmers received about a 9.5% price premium on average, meaning that intermediaries seem to act competitively and are passing the premium through to farmers.

In the Diagnostic Survey, experts were asked whether there is any price premium paid for quality at the producer level. If there is, that would be evidence that there is enough competition that the downstream consumer's premium paid for quality is at least partially

Table 2
Existence of a price premium for quality at the producer level, by crop and country.

Country	Maize	Sorghum	Cassava	Millet	Rice
Burkina Faso	Yes	Yes		Yes	
Burundi	Yes		Yes		
Cameroon	Yes	Yes	No		
Cote D'Ivoire					No
DRC	Yes		No		Yes
Ethiopia	Yes	Yes			
Kenya	No				
Mali	No	No		No	No
Mauritius					
Mozambique	No		No		
Namibia	Yes				
Niger		No		No	
Nigeria	Yes	Yes	Yes		
Rwanda	No	No	No		
Senegal	No	No		No	No
South Africa	No				
Sudan		Yes		Yes	
Swaziland	Yes				
Tanzania	No		Yes		Yes
Togo	Yes	No	No		

passed through to producers. A can be seen in Table 2, results are mixed. Overall, 21 of the 44 commodity/country combinations report a price premium for quality, which is 40% of total cases. Across crops, a premium is reported in 56% of cases for maize, 50% for sorghum, 38% for cassava, and 40% for millet and rice. Interestingly, whether staple crops fetch a premium at the producer level does not vary much within country. Hence, while whether a premium is awarded for quality may very well be a function of crop type, it seems to mainly a function of country-specific markets and institutions. Hence, evidence as to whether condition 2 holds is mixed and varies by crop and context.

5.3. Evidence on the existence of effective certification

To understand whether there currently exist low-cost, credible certification services in Sub-Saharan Africa, we again turn to the Diagnostic Survey. Specifically, we ask the following questions. First, are public quality certification services in existence and available for use for staple crops?[9] Second, are certification services easily accessible to smallholders in being offered at a regional or local branch office? Third, if such services do exist, are smallholders aware of their existence? We consider each in turn.

First, it is the case that in most countries studied (88.8%), public certification services at least nominally exist for staple crops (Table 3); the only countries where they do not are Cameroon and Niger. For particular crops this rate is even higher, reaching 93% of country cases for maize and 100% for rice. Degree of functionality of these services however varies. Expert reports from the DRC, Ethiopia, and Mali noted that certification offices often lack necessary infrastructure and supplies, as well as trained personnel. However, in many other countries like Burkina Faso, Burundi, Kenya, Nigeria, Rwanda, South Africa, and Sudan experts report that public certification services are quite functional. Hence, existence of certification services is widespread, even if functionality is sometimes incomplete.

The second question is about local availability and accessibility. Besides the direct costs of certification services, travel costs may be a binding constraint for some smallholders in obtaining certification. Responses indicate that only 60% of countries have certification services available at a regional or local branch office. In countries such as Burundi, Mali, Mozambique, Rwanda, and Swaziland, certification services are only performed at one central office, which may be quite distant from the farms of rural smallholders. For example, in Mozambique, experts note that certification offices are only located in its capital, Maputo, and hence farmers in other areas cannot easily access the services. Additionally, even countries that do have local and regional branch offices such as Burkina Faso, Ethiopia, Kenya, Tanzania, and Togo, experts note that certification services are either only or mainly offered at the main office. Cost of access is thus a major issue for many potential users.

The third question is: are smallholder farmers aware of the availability of certification services where they exist? While expert survey did not about this directly, they were asked how aware smallholder farmers are about the public grades and standards (G&S), which constitute the quality standards that would be important in certification processes. Overall responses indicate that awareness is very low, only reaching medium to high awareness in 23.5% of countries. It is relatively higher for maize (20%) and millet (25%) and lowest for cassava (0%). Only countries where awareness of these standards for staples are ranked as "medium" or "high" are Kenya, Rwanda, Sudan, and Swaziland.[10] Various experts from countries like Mozambique directly note in the survey that awareness of certification testing services among smallholders is low. Hence it appears to be the case that smallholders face significant information costs in learning about certification services in contexts where they do exist, explaining low use. Notably, the only countries in our survey where public certification services exist and are offered in regional offices, and awareness among smallholders is medium or high are Kenya and Sudan.

Finally, even for contexts where farmers are aware of certification and could benefit from it, these benefits would need to outweigh the costs to be used. While certification costs vary significantly across countries, various experts surveyed (from Burundi, the DRC, Togo for example) report that costs are a key constraint to smallholders using these services. Certification generally costs between USD$ 40–100 per individual service (to certify quality for a given batch presented, based on a sample that is taken from the batch and tested) in countries such as Ethiopia, Kenya, and Togo, and often cost over $100 per service in countries such as Rwanda, Sudan, and Tanzania. Given the scale produced by smallholders in these settings, these costs could comprise a significant portion of their income from the crop, and hence not be profitable. Yet notably, in some countries like Burkina Faso, there is active price discrimination, in the form of discounts for smallholder farmers, in an attempt to not price smallholders out of using the service.

However, to say something definitive about whether these costs are prohibitive for smallholders to use or not, it would be necessary to know smallholders willingness to pay for certification services. While we do not have information on this across contexts, we do have a few examples in the literature. For instance, Abate and Bernard (2017) elicit willingness to pay for wheat certification services by describing certification services to farmers and then asking them if they would be willing to pay a randomly assigned price for the service. They find that over 80% of surveyed farmers report being willing to pay for certification if it is priced at 10–20 birr/quintal. (This is compared to the average base price of about 1000 birr/quintal that farmers receive for their wheat). Yet the percentage of farmers willing to pay for certification declines rapidly as the price increases, with only around 20% willing to pay at a price of 100 birr/quintal. Given that public wheat certification services cost 2500 birr (regardless of the amount of wheat) in Ethiopia currently, if farmers are willing to pay 10 birr/quintal, farmers would need to produce 250 quintals, or 25,000 kg for farmers to want to participate. This is likely significantly more than most smallholders produce. Additionally, we know that such stated preference methods may provide overestimates of true willingness to pay. Hence it is possible that farmers may need to produce even more

[9] Private certification could also be important but expert reports in the diagnostic survey note that few such services exist.

[10] Data is missing for Namibia and Niger has no G&S for the staple crops we study.

Table 3
Smallholder Access to Certification: Percentage of Countries that Produce Each Crop.

Variable	Maize	Sorghum	Cassava	Millet	Rice
Public body that provides testing services exists	93.3%	80.0%	87.5%	80%	100%
Certification is offered at a regional or local branch office	57.1%	62.5%	42.9%	75.0%	75%
High or Medium awareness of certification prevails among smallholders	20.0%	22.2%	0.0%	25.0%	12.5%
Smallholders are able to easily comply with standards	33.3%	44.4%	12.5%	75.0%	50%

Note: There are various missing values for locations where testing services are not present or information is not available, which are excluded from the calculations above.

quantity for certification to be valuable. Though not in Sub-Saharan Africa, we also see another example in the literature of insufficient willingness to pay for a certification technology in the developing world. In Bai (2018) (discussed in Section 5.1), after the intervention was over and the laser cutting technology was no longer provided for free to watermelon sellers, these sellers were not willing to pay for this technology at its market price.

Finally, we noted that certification must be credible for smallholders to want to participate in certification. We have little evidence from either the literature or the diagnostic survey about whether certification is seen as credible. However, again considering Bai (2018), two certification technologies were used: a novel one (a laser-cut label) and an often counter-fitted one (a sticker label). Hence the latter may be seen by consumers as less credible than the former. Results of this study show that Chinese sellers who received the watermelon sticker labels did not experience a significant increase in log sales profits as did those who received the laser cut labeling, and received lower quality premiums than the laser-cut label group as well. Hence this suggests that consumer credibility of the certification technology is critical to success of a certification.

In conclusion, while public certification testing services overwhelmingly tend to exist for staple crops across countries of the developing world and Sub-Saharan Africa, these services are also overwhelmingly not accessible to smallholders in the current state of affairs. From the Diagnostic Survey, there is evidence of significant information costs (awareness), direct costs, and travel costs associated with obtaining certification in all of the countries surveyed. Hence we may find it unsurprising that when asked who are the main clients of certification systems for staple crops in the countries surveyed, we see that in only one case, Senegal, are smallholders listed as one of the main clients. From this evidence, we conclude that access to effective certification for smallholders generally does not exist, and hence sufficient condition 3 does not currently hold for small farmers.

5.4. Evidence of farmers' capacity to produce quality

In order for farmers to respond to certification by improving their crop quality, at least some farmers must have the capacity to invest in quality-enhancing inputs. In terms of our model, the heterogeneous costs of improving quality must be sufficiently low for some farmers that the quality premium received outweigh the cost of improving quality. While there is a dense development literature regarding the "puzzling" lack of adoption of seemingly profitable quality-enhancing technologies in SSA (see for example De Janvry et al., 2016), we suffice it here to say that there often seem to be "low-hanging fruit" in terms of relatively cheap actions that farmers can take to improve their quality. Some examples could include changing seeding methods, cleaning and sorting crops post-harvest, or adjusting the ratio of different fertilizers to obtain an optimal mix. Yet, we note that more generally, other market failures can make adoption of even seemingly cheap technologies costly for farmers. More over Swinnen and Kuijpers (2019) note more generally that a lack of technology does not seem to be a binding factor inhibiting farmers from upgrading their production processes, and that changes in the value chain structure may greatly improve farmers' capacities and willingness to invest in such technologies. (This notion is also explored empirically in the case of Indian dairy production in Janssen and Swinnen (2019).)

Turning back to the Diagnostic Survey and Table 1, we note there is mixed evidence smallholder farmers can currently comply with country G&S in delivering high quality crops. When experts were asked as to whether smallholders can easily comply with public G&S standards for common staples, a positive response was obtained in only 41.2% of the countries overall. Specifically, experts in Burkina Faso, Côte d'Ivoire, Kenya, Mali, Rwanda, Sudan, and Swaziland said yes, but response was no in the other countries.[11] Low compliance is particularly for countries that grow maize (33%) and cassava (12.5%). Various experts note the importance of climactic conditions and farming technologies used in answering this question. In Mali for example, the report notes "agroecological conditions and control of farming techniques very favorable to the production of good quality [by smallholders]", whereas, in Mozambique, experts report that "at the moment very few [smallholders] can compete, simply because most are dependent of [sic] climate conditions. The use of traditional methods cannot enable farmers to meet [quality] standards". Hence while it may be possible for farmers to enhance quality in response to certification in some cases, in others, other technology cost or climactic constraints may bind. Hence, we conclude that whether condition 4 holds varies substantially on a case-by-case basis.

6. Evidence on the success of quality certification in developing country contexts

In order to understand the potential scope for certification in staple food markets in the developing world and Sub-Saharan Africa more specifically, it is helpful to know whether there has been successful implementation of certification in the field and under what conditions. Additionally, it will be helpful to understand whether certification has induced smallholder farmers to produce higher quality, and experience welfare improvements. For this purpose, we consider various experiments in developing country domestic markets which see what occurs when a certification technology and/or information about the usage of such technologies is randomly introduced. We identify two experiments where information about certification technology has been randomly assigned: Abate and Bernard (2017) and Bernard et al. (2017), and three experiments where access to certification technology itself is

[11] Data for Namibia are missing, and Niger has no public G&S standards for the staples in question.

randomly assigned: Saenger et al. (2014), Magnan et al. (2021) and Bai (2018). We discuss each in turn.

Abate and Bernard (2017), as mentioned previously, conduct a randomized experiment with Ethiopian wheat farmers where some farmers are offered training regarding how to measure wheat quality (by measuring test-weight of their wheat and checking the accuracy of the trader's scale) and other farmers are offered this training plus additional training on the potential benefits of cooperative marketing. The authors show that the training interventions did induce farmers to check their wheat's quality before selling (in both treatment groups), check the accuracy of the trader's scale (in the latter treatment group), and contact more than one seller (in the latter treatment group), all actions that could be interpreted as an increase in marketing effort, and resulted in receiving higher prices for their wheat. Moreover, we want to know whether introducing these quality certification tools to farmers in turn resulted in farmers improving quality during the production process. The authors show that farmers in the former treatment group were more likely to use quality-enhancing NPS fertilizer in the following season, knowing that they could now likely earn a premium for this higher quality. However, these quality-enhancing behaviors were not taken up by all treated farmers equally. For example, more remote treated farmers applied less urea fertilizer and had a higher seeding rate than other treated farmers. Perhaps it is the case that because these farmers are so remote, they have less options of traders to sell to, and potentially less bargaining power with these traders, making it less clear that they will get a price premium for their quality-enhancing efforts.

Bernard et al. (2017) consider onion producers in Senegalese markets, where the government of Podor was planning an impending certification intervention in all markets, as detailed previously. While this intervention was set to occur in all markets, some villages randomly received an information intervention before the planting season, telling them about the new certification scheme being introduced in the coming season, in which denser, more nutritious onions would receive a higher certification quality grade. Hence these treatment farmers theoretically were informed about the certification scheme early enough to potentially exert differential effort during the production process to improve onion density. The authors indeed show that farmers in treatment villages were less likely to use urea fertilizer (which results in large, but not dense onions), and more likely to use NPK fertilizer (which results in denser onions). Overall, farmers in treatment villages were more likely to produce bags of onions rated "good quality". Hence farmers in this case did alter input use in order to obtain a higher quality product in response to certification.

In terms of interventions that actually randomize access to a third-party certification service/technology, Saenger et al. (2014) consider Vietnamese dairy farmers that contract with a large buyer called Vinamilk (the largest milk company in Vietnam), and farmers' incentives to exert the quality-enhancing effort of feeding their cows more fodder to improve milk composition (milk fat and total solid content) and quantity produced. While private milk collection centers (intermediaries contracted by Vinamilk) provide a quality assessment to farmers (and are contracted to pay farmers accordingly), Vinamilk (which has much more market power than any individual farmer) could have an incentive to under-report quality in order to pay farmers less. Hence the authors randomly provided some farmers with three non-transferable vouchers for a third-party certifier to come in and verify Vinamilk's quality specification (where the identity of farmers using these vouchers was not visible to Vinamilk). The authors show that farmers who received these vouchers increased the daily concentrate fed per cow, meaning that having the option of third-party certification did increase quality-enhancing input use. However, while treatment farmers produced more milk overall, their milk composition did not improve by a statistically significant amount. In terms of welfare improvements, producers who received access to independent certification experienced a significant increase in total revenue (largely due to the increase in quantity of milk they produced). However, the authors find that this increase in revenue did not translate into a significant increase in household consumption. They hypothesize that as households adjust consumption slowly, they may not have measured consumption over a long enough period of time to see an effect.

Magnan et al. (2021) conduct an intervention with 1005 farmers in Ghana that seeks to understand how paying a premium for aflatoxin-free groundnuts might affect the usage of sanitary drying practices. Among other treatments, they randomly offer some farmers training on aflatoxin safety practices, as well as an offer to sell to a buyer who will pay a premium for their groundnuts that are measured to have aflatoxin content below an allowable (safe) limit. In the first round, the researchers offered a 15% premium above the market price and told farmers that they can call the buyer any time during a period of 2–3 months after harvest, concurrent with the first follow-up survey. However, in this round, there was little take-up from farmers to sell to this premium buyer. The authors hypothesize that take-up may have been low due to the complicated nature of the premiums (percentages may be difficult for farmers to comprehend) and lack of flexibility, as they had to wait some time after harvest to sell to the buyer. Hence in the second round of the experiment, farmers were offered a flat premium of 25 GHC per bag (roughly a 25% premium) and given more flexibility over when they could call the buyer to sell. In this round there was take-up of selling to the premium buyer, and farmers in this group show an 11 percentage point increase over other groups in likelihood to sell to this premium buyer (and a 12 percentage point increase in likelihood of calling the buyer to potentially sell to them). In both years, farmers in this premium buyer treatment group increased their usage of sanitary drying and sorting practices to prevent high aflatoxin levels. However, similarly to the Saenger et al. (2014) case, there is only limited evidence that these improved practices actually led to lower aflatoxin levels on average in either year.

Finally, Bai (2018) considers how providing access to a certification technology to Chinese watermelon retailers affects their quality sorting efforts. While this article deals with certification at the level of a different supply chain link than our main focus of traders and consumers, we include it because: (a) it focuses on certification in a domestic market in a developing country, and (b) sellers in this context are also small enterprises which are selling directly to consumers. As detailed in the previous section, this article involves an experiment where some Chinese watermelon sellers were randomly given a quality certifying technology–either a "high quality" sticker (which is often counter-fitted and hence may be a "contaminated" quality signal) or a novel laser-cut printed label (which is likely "uncontaminated"). She finds that sellers in the laser-cut label group are more likely to accurately sort higher quality melons into the high-quality pile and experience increased sales profits, and this is also true, but to a lesser extent, for the sticker label group. Yet, as mentioned previously, one year after the intervention when the laser technology was no longer provided for free, all markets reverted back to baseline, suggesting that small individual sellers find the technology too expensive to invest in absence of the intervention.

Additionally, the literature focused on smallholder farmer participation in high-value global export chains provides additional experimental evidence that smallholders respond to the potential of earning a price premium associated with meeting more stringent quality standards by exerting more effort. Macchiavello and Miquel-Florensa (2017), mentioned above, exploit the staggered roll-out of the Quality Sustainability Program to Colombian coffee farmers to show how farmers' quality-enhancing efforts respond to a 10% price premium. They observe that farmers eligible to participate substituted old, unproductive trees with younger trees of disease-resistant varieties. Eligible farmers also produced better quality coffee on average, in attributes such as percentage of healthy beans. Yet as the program studied also contained supplemental benefits to farmers, such as extension services and access to inputs for plot renewal, it is challenging to say whether quality-upgrading by farmers was solely due to the promised price premium. The authors also use a structural model to estimate welfare effects for program farmers. They find that the Quality Sustainability Program increases overall domestic value chain surplus by about 33%, with over half (19%) accruing to smallholder program coffee producers. In more concrete terms, they find that conditional on take-up, the Program increased farmers profits by 17% (without, by assumption in their model, reducing the profits of non-participants).

The experiments considered above show that in various developing country contexts, when smallholder farmers and other value chain actors are given an incentive to produce higher quality with the introduction of a certification system or technology, many will indeed choose to make quality-enhancing efforts. However, we note that not all producers will upgrade their quality, only those who find it in their best interest to do so. If the cost of upgrading is too high (as is the case for farmers not purchasing a laser-cut printer to certify watermelon quality in China post-experiment in Bai, 2018), or the benefit is too low (as is perhaps the case in Abate and Bernard, 2017 where remote treated farmers use less fertilizer and higher seeing rates), farmers may not engage in such behavior. Additionally, we see some evidence that farmers that do choose to upgrade their quality in response to the availability of certification experience some welfare benefits.

7. Conclusion

Using the results from a diagnostic survey across 20 countries of Sub-Saharan Africa, we observe that public quality certification systems for staple foods on domestic markets are broadly present, but that smallholder farmers currently make little use of them. This is in spite of the significant asymmetric information problems that could be solved by certification. Current lack of recognition exposes domestic farmers to loss of competitiveness with imported foods in meeting rising processor and consumer demand for quality staple foods. Constructing a model helps predict that benefits from certification could include higher prices received by farmers for higher quality, production of higher quality in response to higher prices, and welfare benefits for farmers with ability to deliver higher quality.

8. Policy implications

Using both the sufficient conditions of the model, results obtained by others in analyzing certification in value chains, and inspection of successful cases of certification, we find that four conditions need to hold for certification to succeed: (1) willingness to pay for quality downstream in the value chain, particularly by processors and major retailers on behalf of consumers; (2) sufficient competition among traders upstream in the value chain for price passing through to farmers to occur; (3) availability of certification that is informed, accessible, low-cost, and credible, and happens before smallholder product aggregation without traceability occurs; and (4) existence of farmers with capacity to respond to quality price incentives, with high smallholder farmer inclusion among switchers to secure broad welfare benefits. From our review of evidence, we see that evidence that these conditions currently hold in practice is extremely mixed. Additionally, the extent to which these conditions are met, may itself be an endogenous response to the particular conditions of smallholder-based staple crops value chains, which is to be further examined in future work.

Yet observing that there is no downstream demand for quality in many domestic staple crop markets, that various intermediaries in such markets do not act in a competitive manner, and that there do not exist many low cost certification services that are accessible to smallholders, this lack of use by smallholder farmers can be rationalized.

These conditions provide governments with actionable policy instruments to achieve success in introducing quality certification systems that can be used by smallholder farmers. Careful attention to implementing this policy agenda can be an effective way of preserving the livelihoods of millions of farm households in competitively supplying emerging urban consumers with staple foods in the face of globalization.

CRediT authorship contribution statement

Gashaw T. Abate: Conceptualization, Methodology, Investigation, Writing – review & editing, Supervision, Funding acquisition. **Tanguy Bernard:** Conceptualization, Methodology, Investigation, Writing – review & editing, Supervision, Funding acquisition. **Alain de Janvry:** Conceptualization, Methodology, Writing – review & editing, Visualization, Supervision, Project administration, Funding acquisition. **Elisabeth Sadoulet:** Conceptualization, Methodology, Writing – review & editing, Supervision, Project administration, Funding acquisition. **Carly Trachtman:** Conceptualization, Methodology, Formal analysis, Writing – original draft, Writing – review & editing, Visualization.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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