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Intermediaries, transport costs and interlinked transactions

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Abstract

Farmers in developing countries often encounter difficulties selling their products on local markets. Inadequate transport infrastructure in rural areas and large distances between areas of production and consumption mean that farmers find it costly to bring their produce to the market and this very often results in small net margins and poverty among farmers who are geographically isolated. Agriculture in developing countries is characterized by the presence of intermediaries that have a cost advantage over farmers. Because of their market power, these intermediaries are able to impose interlinked contracts and are free to choose the spatial pricing policy they use. In this paper, we develop a model of input–output interlinked contracts between an intermediary and geographically dispersed farmers. We establish when the intermediary uses either uniform or mill pricing policies, as opposed to spatial discriminatory pricing. For each pricing policy, we analyze what the welfare implications are in terms of an increase in farmers' income and a reduction in poverty in rural areas. We also establish how the choice of a spatial pricing policy impacts geographically isolated farmers and how it influences the participation by farmers.

1 | INTRODUCTION

Smallholder farming constitutes about 80 percent of African agriculture. Five hundred million of such farms provide income to about two-thirds of the 3 billion rural people in the world (IFAD, 2013). While a large number of individuals in rural areas in developing countries depend on it, small-scale agriculture has suffered since the 1980s with globalization and agro-industrialization causing small farms to go out of business (Reardon & Barrett, 2000). Small farmers' access to land has been shown to decrease over time (Jayne, Yamano, & Nyoro, 2004). Furthermore, the World Bank (2007) reports that an estimated 75 percent of poor people in developing countries live in rural areas. Most of them depend directly or indirectly on agriculture for their livelihoods. In South Asia and Sub-Saharan Africa, the number of poor people in rural areas is still increasing and is expected to stay above the number of urban poor, at least until 2040 (World Bank, 2007). The prevalence of hunger is still greater in rural than in urban areas (Von Braun, Swaminathan, & Rosegrant, 2004) and rural children are nearly twice as likely to be underweight as urban ones (World Bank, 2011).

Different reasons explain the decline of small-scale agriculture in developing countries. High transport costs are one of them. Small-scale farmers face high transport costs to reach local markets because of inadequate rural transport infrastructures, combined with large distances between areas of production and areas of consumption. Transport costs also affect farmers negatively through the cost of access to inputs that reduce both input use and agricultural production (Staal, Baltenweck, Waithaka, De Wolff, & Njoroge, 2002; Holloway, Nicholson, Delgado, Staal, & Ehui, 2000). Isolated farmers are less productive (Stifel & Minten, 2008; Binswanger, Khandker, & Rosenzweig, 1993) and have lower incomes (Jacoby, 2000) than farmers who have an easier access to the market. Small-scale farms are especially affected as they are unable to make the necessary investments to overcome the disadvantage linked to these transport costs.

Evidence suggests that agriculture in developing countries is increasingly characterized by smallholder farmers producing commodities on contract with agro-industrial firms (International Fund for Agricultural Development [IFAD], 2003). In Mozambique, 12 percent of the rural population is working on a contract basis with local enterprises that are affiliated with international companies. In Kenya, 85 percent of sugar cane production depends on small-scale farmers who provide their production to sugar companies. These intermediaries often have some advantage over farmers. They can, for example, transport goods to the location of consumption at a lower cost (transporting them in larger quantities with trucks, transforming them to reduce their volume and/or perishability, etc.), or they can transform the product enabling them to charge a higher price. Obtaining this advantage often requires incurring an important fixed cost, which farmers cannot make. Examples of such intermediaries include maize, beans, roots, and tubers in Malawi and Benin (Fafchamps & Gabre-Madhin, 2006), mandarin in Nepal (Pokhrel & Thapa, 2007), and cashews in Mozambique (McMillan, Welch, & Rodrik, 2003).

Hence the question is whether contracting with these intermediaries leads to an increase in farmers' incomes. If this is the case, then helping setting up these intermediaries (through, e.g., grants or subsidies) would be another way to reduce poverty in rural areas. However, contracts between intermediaries and farmers involve interlinked transactions. The intermediary not only buys the agricultural output from the farmer, but also provides him with the input that is necessary for his production with the price of both goods being simultaneously fixed. The use of these contracts has been documented for various countries and sectors [see for instance Warning and Key (2002) for the groundnut sector in Senegal; Jayne et al. (2004) for cash crops production in Kenya; Simmons, Winters, and Patricks (2005) for various Indonesian sectors; or Key and Runsten (1999) for the Mexican frozen vegetable industry]. Existing theoretical work, for example, Gangopadhyay and Sengupta (1987), suggests that because of the use of interlinked contracts farmers would not benefit from the intermediaries' lower costs. They show that these contracts lead to an efficiency gain, but also that this gain is completely appropriated by the intermediary. This result depends on the assumption that the intermediary can set a different contract for each farmer. In a spatial context, this corresponds to assuming that the intermediary can perfectly price discriminate between spatially dispersed farmers. It collects the product from farmers and sets a different farmgate price. However, other pricing policies besides spatial price discrimination are used by intermediaries.

In this paper, we analyze interlinked contracts in a spatial context where an intermediary faces geographically dispersed farmers and is free to choose its spatial pricing policy. We establish what spatial pricing policy is used by an intermediary and how this policy affects farmers. Besides discriminatory pricing, we also consider uniform pricing by which the intermediary proposes the same farmgate prices to all farmers. Public authorities used to be involved in the marketing of agricultural products through marketing boards and used "pan-territorial pricing" (i.e., uniform pricing) to encourage production by poor farmers located in remote areas. With economic liberalization in developing countries in the 1980s and 1990s, several state marketing boards have disappeared and been replaced by private marketing intermediaries with market power (Barrett & Mutambatsere, 2008). With the disappearance of state marketing boards, uniform pricing is no longer the only pricing policy used. Another policy is mill pricing where farmers rather than the intermediary are in charge of the transport of the good. Mill prices are the same for all farmers at the location of the intermediary. With mill pricing, we have the added complication that because farmers support transport costs both reservation and contract income vary with location. Hence farmers' rents may fail to be monotonic and a farmer located in the interior of the rural area could be at his reservation level, while others obtain positive rents. Because of this possibility, we cannot use the standard approach in contract theory, which relies heavily on the monotonicity of the rent, and use an alternative approach to characterize the optimal contract.

In Section 2, to illustrate the ideas of our paper, we describe some features of the milk sector in Senegal, which is characterized by the presence of intermediaries who use interlinked transactions and where transport costs are high. Section 3 presents the model and its assumptions. Sections 4, 5, and 6 analyze an interlinked transaction model for a for-profit intermediary that uses respectively spatial price discrimination, uniform pricing, and mill pricing. In Section 7 we compare the impact of each pricing policy on the optimal size of the catchment area, the intermediary's profit, regional differences in farmers' income, levels of production, and poverty among farmers. Finally, Section 8 concludes.

2 | CHARACTERISTICS OF THE MILK SECTOR IN SENEGAL

In Senegal 48.12 percent of the population (73.48 percent in rural areas) own cattle (Enquête de Suivi de la Pauvreté au Sénégal [ESPS], 2005). Most of them are poor: 63.28 percent of households involved in agriculture, livestock, and forest employment face poverty compared with 37.82 percent in other employment. As in most African countries, increasing domestic dairy production in Senegal could generate additional income and reduce poverty of a large part of the population (Staal, Delgado, & Nicholson, 1997; Delgado, Rosegrant, Steinfeld, Ehui, & Courbois, 1999).

Although still low compared with the rest of the world, milk consumption by African households has increased. In Senegal, before the 1994 Central African franc (CFA franc) devaluation that decreased it, total consumption quadrupled during the period 1961 to 1993. Despite this increased consumption, the domestic milk production has risen by less than 40 percent during the same period, most of the demand being satisfied by an increase in imports. According to Duteurtre (2006), the quantity of milk imported is twice the level of production in Senegal.

This lack of increase in production is due to different elements. Farmers have only few cows, each providing small quantities of milk (between 0.5 and 2 liters of milk per day, see Duteurtre, 2006). The productivity per animal is determined by its breed (local cattle breeds, Zebu Gobra, Taurine N'Dama, and D'jakoré are known to have low productivity) but also by the quantity of animal feed used. A major constraint for improving milk production is the difficulty for farmers to obtain these cattle feeds (Dieye, Duteurtre, Sissokho, Sall, & Dia, 2005; Dieye, 2003).

Another factor that hampers the increase of production are high transport costs. Areas of milk production are far from the capital city, Dakar, where most of the consumers are located (360 km for Richard-Toll where La Laiterie du Berger operates, 250 km for Dahra, which is the DINFEL [*Directoire national des femmes en élevage*] collection area). On average, households' expenditure for milk consumption is 218 CFA francs per day in Dakar whereas it is 107.5 CFA francs in other regions (ESPS, 2005). In the rural area, the transport cost is important compared with the price received by farmers. In Kolda, where the price received by the producers ranges between 75 and 150 CFA francs, transport by bicycle costs between 20 and 25 CFA francs per liter (Dia, 2002). Motorized transport is even more costly; according to one of the managers of La Laiterie du Berger (personal interview, 2009), average transport cost on its collection area is 100 CFA francs per liter, while farmers receive 200 CFA francs per liter. As incurring large costs for transporting small quantities of milk may turn out to be unprofitable, farmers often prefer not, or only occasionally, to sell their milk production in the market. In a similar context in Ethiopia, Holloway et al. (2000) found that each additional minute walk to the collection center reduces the marketable quantity of milk by 0.06 liters per day. In a region where milk yields per day are less than 4 liters, this is of considerable importance. High transport costs also have a negative impact on the use of feed supplements. In Kenya, whose milk sector is comparable with the Senegalese one, Staal et al. (2002) have found that an additional 10 kilometers between the farmer and Nairobi decreases the probability of using concentrate feed by more than 1 percent. This difficulty of selling to the market for isolated farmers contributes to them remaining in poverty. In Senegal, while poverty is 35percent among households who are able to reach a food market in less than 15 minutes, it increases to 63 percent for those who have to travel more than 1 hour to reach such a market. This group represents a relatively large share of the population (20 percent).

Since the 1990s, small-scale processing units, called "mini-dairies," which play the role of an intermediary between farmers and the market, have emerged in Senegal and other West African countries (Dieye et al., 2005; Corniaux, Duteurtre, Dieye, & Poccard-Chapuis, 2005). They have a cost advantage over farmers as they use trucks to transport milk over large distances and they own bulk cooling tanks allowing them to stock milk and hence eliminating the need to transport it every day to the market. In Senegal in the 1990s, milk production, which stagnated for 30 years, began to increase. Based on a survey conducted in 2002 in Kolda (Southern Senegal), Dieye et al. (2005) have reported that quantities of milk collected by small-scale processing units in this area increased (21,250 liters in 1996, 113,600 liters in 2001, 214,205 liters in 2003) while the number of processing units increased during that period from 1 to 8 (Dieye, 2006). The same pattern is observed in the other regions (Broutin, 2005, 2008). Farmers tend to sell small quantities of milk. Sometimes milk from cows belonging to different owners are combined in one churn and this is brought to a pick-up point. According to Duteurtre (2006), in Senegal the rate of commercialization of milk has been increasing.

Contracts between mini-dairies and farmers often involve interlinked transactions. In the region of Kolda, Dieye et al. (2005) report that milk processing units provide credit and cattle feed to farmers in order to increase production. The two most important mini-dairies in this region ("Bilaame Puul Debbo" and "Le Fermier") use three different mechanisms for linking milk purchase and the selling of animal feed: credit for feed purchase, direct feed purchase for the farmer, or guarantee to the feed seller in case of nonpayment by the farmer (Dieye, 2006). In Northern Senegal, La Laiterie du Berger buys large quantities of cattle feeds and resells it to the farmers at 50 percent of the market price (Bathily, 2007).

To our knowledge, spatial price discrimination is not used in the milk sector in Senegal. To illustrate uniform and mill pricing we focus on two mini-dairies. La Laiterie du Berger organizes milk collection and pays all farmers the same price, independently of the distance. This corresponds to uniform pricing. “Le Fermier”, however, uses mill pricing where farmers are responsible for transport.

3 | MODEL

Geographical locations are represented along a line. An urban center in which an agricultural good is sold at price p is located at the origin 0 (see Figure 1). The different agents do not have an impact on this price, which is determined on world markets. A position x on this line represents a geographical location at a distance x from the market. A rural area starts at a distance r from the urban center and has a geographical extent R. Farmers are uniformly distributed over this rural area.

Each farmer produces the agricultural good according to the same production function $f(\underline{k})$, where k is the quantity of input he uses. This input is sold at price i on the market at location 0. The production function has the usual properties: $f(.)$ is twice continuously differentiable, $f(0) = 0$, $f_k = \frac{df}{dk} > 0$, $\lim_{k\to 0} f_k = \infty$, $\lim_{k\to\infty} f_k$ and $\frac{d^2f}{dk^2} < 0$. A farmer located at x facing farmgate prices $p_F(x)$ and $i_F(x)$ maximizes his income $y(p_F(x), i_F(x))$ by using the optimal quantity $k(p_F(x), i_F(x))$ (for simplicity, as long as it does not cause any confusion, notations $y(x)$ and $k(x)$ will be used):

$$\max_{k(x)} y(x) = p_F(x) f(k(x)) - i_F(x) k(i). \tag{1}$$

The optimal input quantity satisfies the following necessary condition:

$$\frac{df}{dk} = i_F(x) p_F(x). \tag{2}$$

Transport costs have to be incurred by farmers to bring this good to the market. These costs $t(x)$ are assumed to be linear in distance x and hence $t(x) = \tau x$. To simplify we assume that

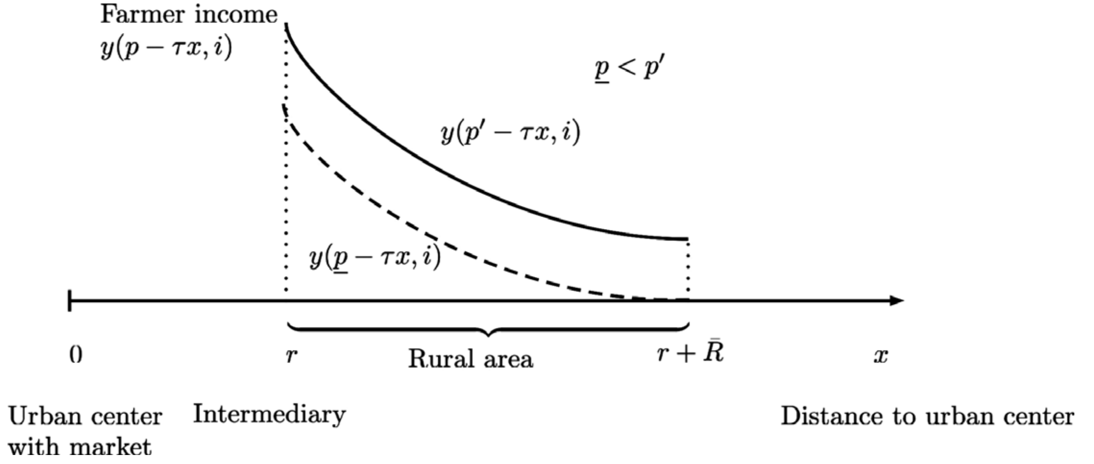

FIGURE 1 The model

transport costs are negligible for the input and set them equal to zero.[1] A farmer located at a distance x from the market $t(x) = \tau x$ obtains a net per unit output price $p_F(x) = p - \tau x$. We assume that in the rural area farmers are able to make a living and hence consider only prices $p > \underline{p}(R)$ where $\underline{p}(R)$ is defined by $y(\underline{p} - \tau(r + R), i) = 0$.

An intermediary located at r with a cost advantage over farmers offers them contracts.[2] Here, we assume that the cost advantage is the ability to transport the good between 0 and r at a lower cost: the transport costs from location x to the urban market are given by $t(x) = r + \tau(x - r)$ per unit of output transported, with $\theta < \tau$.[3] The intermediary buys the output from the farmers and sells them an input necessary for their production.[4] Prices for both input and output are simultaneously fixed in the contract between the intermediary and the farmer. The intermediary sells the output and buys the input on the market located in 0, at market price p and i respectively.

The intermediary proposes a contract $(p_C(x), i_C(x))$ to each farmer located on the segment $[r, r + R]$.[5] The farmer located at x receives $p_C(x)$ per unit of output and pays $i_C(x)$ per unit of input.[6] Each farmer can individually accept or reject the contract. If he accepts the contract, he faces prices $(p_C(x), i_C(x))$ and chooses optimal input use $k^*(x) = k(p_C(x), i_C(x))$. If he rejects the contract, he sells his production directly to the market and buys himself the inputs. In this case, the optimal amount of input is $k^0(x) = k(p - \tau x.i)$, which depends on market prices (p, i) and transport costs. Output is produced and sold on the market, either directly by the farmer (if the contract is rejected) or via the intermediary (if the contract is accepted).

The intermediary's problem is:

$$\max_{p_C(x), i_C(x)} \Pi = \int_r^{r+R} [(p - \theta r - \tau(x - r) - p_C(x))f(k^*(x)) + (i_C(x) - i)k^*(x)]dx - F \tag{3}$$

subject to (2) and the participation constraints:

$$y(x) \equiv p_C(x)f(k^*(x)) - i_C(x)k^*(x) \geq y^0(x) \equiv (p - \tau x)f(k^0(x)) - ik^0(x) \tag{4}$$

for all $x \in [r, r + R]$ and where F is the fixed cost necessary to obtain the cost advantage.[7]

In the following sections we establish what the optimal contract $(p_C(x), i_C(x))$ is for the different spatial pricing policies that the intermediary can use. Each pricing policy leads to a different input use by farmers and can lead to differences in income of farmers at different locations x.

4 | SPATIAL PRICE DISCRIMINATION

The intermediary proposes a contract $(p_D(x), i_D(x))$ for each location x. Each farmer can individually accept or refuse the contract proposed. Hence, to maximize his total profit, the intermediary chooses a contract that maximizes the profit he makes at each location.

Using Equations 3 and 4, the intermediary's problem can be written as:

$$\max_{p_D(x), i_D(x)} \pi(x) = (p - \theta r - \tau(x - r))f(k^*(x)) - ik^*(x) - (p_D(x)f(k^*(x)) - i_D(x)k^*(x)) \tag{5}$$

$$\text{s.t. } g(x) \equiv p_D(x)f(k^*(x)) - i_D(x)k^*(x) - y^0(x) \geq 0. \tag{6}$$

The Lagrangian is given by:

$$\begin{aligned} L = &(p - \theta r - \tau(x - r))f(k^*(x)) - ik^*(x) + (\lambda(x) - 1) \\ &\times (p_D(x)f(k^*(x)) - i_D(x)k^*(x)) - \lambda(x)y^0(x). \end{aligned} \tag{7}$$

Noting that at the optimum $\frac{df}{dk} = \frac{i_D(x)}{p_D(x)}$ and applying the envelope theorem to the income of the farmer, the Kuhn–Tucker conditions are:

$$\frac{\partial L}{\partial p_D(x)} = \left((p - \theta r - \tau(x-r)) \frac{i_D(x)}{p_D(x)} - i \right) \frac{\partial k^*(x)}{\partial p_D(x)} + (\lambda(x) - 1) f(k^*(x)) = 0 \tag{8}$$

$$\frac{\partial L}{\partial i_D(x)} = \left((p - \theta r - \tau(x-r)) \frac{i_D(x)}{p_D(x)} - i \right) \frac{\partial k^*(x)}{\partial i_D(x)} + (\lambda(x) - 1)(-k^*(x)) = 0 \tag{9}$$

$$\lambda(x) \geq 0, \quad g(x) \geq 0, \quad \lambda(x) g(x) = 0. \tag{10}$$

Multiplying (8) by $p_D(x)$ and (9) by $i_D(x)$, adding these two expressions up, and because input demand $k^*(x)$ is homogeneous of degree zero in both prices, this yields:

$$(\lambda(x) - 1)(p_D(x) f(k^*(x)) - i_D(x) k^*(x)) = 0. \tag{11}$$

If the second term were equal to zero, this would imply that $y(x) = 0$ so that $g(x) < 0$, contradicting (10). Thus, the first term is equal to zero, implying that $\lambda(x) = 1$. Substituting this in either of the first order conditions yields:

$$\frac{i_D(x)}{p_D(x)} = \frac{i}{p - \theta r - \tau(x-r)}. \tag{12}$$

Equation 12 characterizes the optimal contract $(p_D(x), i_D(x))$. This contract induces the farmer to increase his level of input compared with the stand-alone case, even though he receives the same income.

Proposition 1. *Under spatial price discrimination, the intermediary induces each farmer to use a quantity of inputs that is larger than in his stand-alone situation ($k^*(x) > k^0(x)$), while keeping the farmer at his reservation income level ($y(x) = y^0(x)$).*

Proof. Given that $\tau > \theta$ and that $f(k)$ is strictly concave and using (2) with respectively $(p_F(x), i_F(x)) = (p_D(x), i_D(x))$ and $(p_F(x), i_F(x)) = (p - \tau x, i)$, we have that $k^*(x) > k^0(x)$. Since $\lambda(x) = 1$, we have from (10) that $g(x) \equiv p_D(x) f(k^*(x)) - i_D(x) k^*(x) - y^0(x) = 0$.□

Substituting (12) in the binding participation constraint $g(x) = 0$ gives:

$$p_D(x) = (p - \theta r - \tau(x-r)) \underbrace{\frac{(p - \tau x) f(k^0(x)) - i k^0(x)}{(p - \theta r - \tau(x-r)) f(k^*(x)) - i k^*(x)}}_{\equiv \eta_D(x)} \tag{13}$$

$$i_D(x) = i \underbrace{\frac{(p - \tau x) f(k^0(x)) - i k^0(x)}{(p - \theta r - \tau(x-r)) f(k^*(x)) - i k^*(x)}}_{\equiv \delta_D(x)}. \tag{14}$$

With these prices, arbitrage between farmers is impossible: it can be shown that a farmer at any location x has no interest in transporting the good to another location z in order to benefit from a higher output price $p_D(z)$ and/or lower input price $i_D(z)$. The potential gain from such an action is always lower than the incurred transport cost.

Corollary 1. *Under spatial price discrimination, the intermediary "loses" on the input trading ($i_D(x) < i$) and "gains" on the output trading ($p_D(x) < p - \theta r - \tau(x - r)$).*

Proof. From Proposition 1, $\eta_D(x) = \delta_D(x)$ and this can be written as:

$$\eta_D(x) = \delta_D(x) = \frac{\max_k (p - \tau x) f(k) - ik}{\max_k (p - \theta r - \tau(x - r)) f(k) - ik}.$$

Using the envelope theorem and since by assumption $\theta < \tau$, this implies that $\eta_D(x) = \delta_D(X) < 1$. Using this result with (13) and (14) implies that $p_D(x) < p - \theta r - \tau(x - r)$ and $i_D(x) < i$ □

Gangopadhyay and Sengupta (1987) analyze interlinked contracts when the input market is characterized by an imperfection, such that the farmer faces a higher input price than the firm. They show that the intermediary has an interest to "subsidize" the input and "tax" the output, and that this type of contract allows him to appropriate all the efficiency gain. In our context, the difference between the intermediary and the farmer lies in the (output) transport costs, and the previous analysis shows that their results remain valid in this context. Both output and input prices are necessary for the intermediary to capture the efficiency gain completely. In different contexts evidence suggests that in interlinked contracts the input is sold at a discount.[8]

Corollary 2. *Under spatial price discrimination, each farmer "gains" on the input trading ($i_D(x) < i$) and "loses" on the output trading ($p_D(x) < p - \tau x$).*

Proof. From (13), $p_D(x) < p - \tau x$ if

$$f(k^0(x)) - \frac{i}{p - \tau x} k^0(x) < f(k^*(x)) - \frac{i}{p - \theta r - \tau(x - r)} k^*(x).$$

From (2) and (12), this is equivalent to

$$f(k^0(x)) - \left.\frac{df}{dk}\right|_{k(x)=k^0(x)} k^0(x) < f(k^*(x)) - \left.\frac{df}{dk}\right|_{k(x)=k^*(x)} k^*(x).$$

This is true provided that the production elasticity $\frac{df}{dk}\frac{k}{f(k)}$ is constant or decreasing in k. The result $i_D(x) < i$ follows from Corollary 1. □

With an interlinked contract, each farmer receives a price for the output that is lower than the net price he would have received in the stand-alone situation. This "loss" on the output trading is compensated by a "gain" on the input trading, such that each farmer obtains an income $y(x)$ from the contract, which is exactly equal to his reservation income $y^0(x)$.

Depending on their location, farmers are treated differently: those located far from the market receive a lower price for their output, but they also pay a lower price for input. Moreover, those farmers receive a smaller share of the net price received by the intermediary on the market for the output and pay a lower part of the input price. Indeed, from (13) and (14), it can be shown that $p_D(x)$, $i_D(x)$, and $\eta_D(x) = \delta_D(x)$ are decreasing in x. These results seem to indicate that the presence of an intermediary with a cost advantage leads to an increase of production, but this does not benefit farmers. Hence setting up intermediaries would not be a way to help farmers. However, spatial pricing discrimination is only one possible pricing policy.

5 | UNIFORM PRICING

With uniform pricing policy, the intermediary proposes to farmers the same contract (p_U, i_U), which is independent of their location x. Each farmer can individually accept or refuse the contract proposed.

The intermediary's problem can be written as:

$$\max_{p_U, i_U} \Pi = \int_r^{r+R} [(p - \theta r - \tau(x-r))f(k^*) - ik^* - (p_U f(k^*) - i_U k^*)]dx$$

$$\text{s.t. } g(x) \equiv p_U f(k^*) - i_U k^* - y^0(x) \geq 0 \quad \forall x$$

where k^* is the same for all locations and given by (2) where $p_F(x) = p_U$ and $i_F(x) = i_U$. There is a continuum of participation constraints $g(x)$ with $x \in [r, r + R]$. However, as k^* is constant for all x and $y^0(x)$ is strictly decreasing in x, $g(x)$ is strictly increasing in x. Hence if the constraint is satisfied for the farmer located at r, the constraints are satisfied for all farmers at $x \in]r, r + R]$. We can replace the continuum of constraints $g(x) \geq 0$ by the unique constraint $g(r) \geq 0$ (see for instance Bolton & Dewatripont, 2005). The Lagrangian can be written as:

$$L = R\left(\left(p - \theta r - \tau\frac{R}{2}\right)f(k^*) - ik^*\right) + (\lambda - R)(p_U f(k^*) - i_U k^*) - \lambda y^0(r) \tag{15}$$

Noting that at optimum $\frac{df}{dk} = \frac{i_U}{p_U}$ and applying the envelope theorem to the farmer's income, the Kuhn–Tucker conditions can be written as:

$$\frac{\partial L}{\partial p_U} = R\left(\left(p - \theta r - \tau\frac{R}{2}\right)\frac{i_U}{p_U} - i\right)\partial k^* \partial p_U + (\lambda - R)f(k^*) = 0 \tag{16}$$

$$\frac{\partial L}{\partial i_U} = R\left(\left(p - \theta r - \tau\frac{R}{2}\right)\frac{i_U}{p_U} - i\right)\partial k^* \partial i_U + (\lambda - R)(-k^*) = 0 \tag{17}$$

$$\lambda \geq 0, \quad g(r) \geq 0, \quad \lambda g(r) = 0. \tag{18}$$

Multiplying (16) by p_U and (17) by i_U, adding these two expressions up and noting that the input demand k^* is homogeneous of degree zero in both prices, we have

$$(\lambda - R)(p_U f(k^*) - i_U k^*) = 0. \tag{19}$$

If the last term were equal to zero, this would imply that $y(r) = 0$ such that $g(r) < 0$, contradicting (18). Thus we have $\lambda = R$ and hence using either first order condition:

$$\frac{i_U}{p_U} = \frac{i}{p - \theta r - \tau\frac{R}{2}}. \tag{20}$$

Equation 20 characterizes the optimal contract (p_U, i_U) This contract implies that each farmer receives the same income from the contract as the stand-alone income of the first farmer.

Proposition 2. *Under uniform pricing, if the collection area is not too large ($\tau r - \theta r > \tau(R/2)$), the intermediary induces each farmer to increase his quantity of inputs with respect to the stand-alone situation ($k^*(x) > k^0(x)$) and keeps the closest farmer at his reservation level ($y(r) = y^0(r)$) while the other farmers obtain a positive surplus from the contract. If the collection area is large ($\tau r - \theta r \leq \tau(R/2)$), he is not able to make a positive profit.*

Proof. Since $\lambda = R$, we have from (18) that $g(r) \equiv p_U f(k^*) - i_U k^* - y^0(r) = 0$. If $\tau r - \theta r > \tau(R/2)$, given that $f(k)$ is strictly concave and using (2) with respectively $(p_F(x), i_F(x)) = (p_U, i_U)$ and $(p_F(x), i_F(x)) = (p - \tau x, i)$, we have that $k^* > k^0(x)$. If $\tau r - \theta r \leq \tau(R/2)$, we have that $k^* \leq k^0(x)$. Given that $g(r) = 0$, the profit is $\Pi = R((p - \theta r - \tau\frac{R}{2})f(k^*) - ik^* - [(p - \tau r)f(k^0(r)) - ik^0(r)])$. From $k^* \leq k^0(r)$ and $\tau r \leq \theta r + \tau(R/2)$, we have that $\Pi \leq 0$. □

La Laiterie du Berger claims that the feed supplements it provides to the farmers have helped them to increase their production, especially during the dry season (personal interview, 2009). Contrary spatial price discrimination, when the intermediary is able to operate profitably under uniform pricing, all farmers, except the first one, obtain a higher income compared with their stand-alone situation. Using this policy, La Laiterie du Berger claims that its presence has allowed to triple the income of the farmers involved (PhiTrust, 2011).[9]

Substituting (20) in the binding participation constraint $g(r) = 0$ gives:

$$p_U = \left(p - \theta r - \tau\frac{R}{2}\right)\underbrace{\frac{(p - \tau r)f(k^0(r)) - ik^0(r)}{(p - \theta r - \tau\frac{R}{2})f(k^*) - ik^*}}_{\equiv \eta_U} \tag{21}$$

$$i_U = i\underbrace{\frac{(p - \tau r)f(k^0(r)) - ik^0(r)}{(p - \theta r - \tau\frac{R}{2})f(k^*) - ik^*}}_{\equiv \delta_U} \tag{22}$$

Corollary 3. *Under uniform pricing, when $\tau r - \theta r > \tau(R/2)$, the intermediary "loses" on the input trading ($i_U < i$) and "gains" on average on the output trading ($p_U < p - \theta r - \tau(R/2)$).*

Proof. Given that k^* is defined by (20), we can write $\eta_U = \delta_U$ as:

$$\eta_U = \delta_U = \frac{\max_k (p - \tau r)f(k) - ik}{\max_k (p - \theta r - \tau(R/2))f(k) - ik}.$$

Using the envelope theorem, $\tau r - \theta r > \tau(R/2)$ implies that $\eta_U = \delta_U < 1$. Using this result with (21) and (22) implies that $p_U < p - \theta r - \tau(R/2)$ and $i_U < i$. □

Propositions 2 and 3 imply that, when using uniform pricing, the intermediary is able to make a positive profit only if there exists a sufficient advantage in transport cost, that is, $\tau r - \theta r > \tau(R/2)$.[10] In this case also, he "loses" on the input trading and "gains" on the output trading, as the average net price he receives on the market is higher than the price he pays to each farmer. The strategy of La Laiterie du Berger that sells cattle feed to farmers at 50 percent of the market price (personal interview, 2009) is thus consistent with our analysis. However, if his cost advantage is too small, he is not able to profitably induce farmers to organize production in a more efficient way. This result is in contrast with the result obtained under price discrimination, where the intermediary is able to exploit his cost advantage, even if the advantage is very small.

6 | MILL PRICING

Under mill pricing, the intermediary proposes the same contract (p_M, i_M) to all farmers (where p_M and i_M are independent of x) and farmers have to pay for transporting the good to the intermediary. Thus, the net price for the output received by the farmer at location x is $p_F(x) = p_M - \tau(x - r)$.

From Equations 3 and 4, the intermediary's problem can be written as:

$$\max_{p_M, i_M} \Pi = \int_r^{r+R} [(p - \theta r - p_M) f(k^*(x)) + (i_M - i) k^*(x)] dx \tag{23}$$

$$\text{s.t.} \quad g(x) \equiv (p_M - \tau(x - r)) f(k^*(x)) - i_M k^*(x) - y^0(x) \geq 0 \quad \forall x.$$

Here also, there is a continuum of participation constraints $g(x) \geq 0$ with $x \in [r, r + R]$. Contrary to the uniform pricing case, which constraint(s) will be binding at the optimum is a priori not obvious. As he is in charge of transport in the no-contract case and under mill pricing, the net price the farmer obtains decreases with distance. Consequently, both no-contract income as well as income under mill pricing decrease with distance at a nonconstant rate. Because of this, it is easy to see that we may have that the constraint is only binding at either end of the interval, but we may also have a case where one or several interior agents face binding participation constraints while agents at the "extremes" of the rural area do not. We show in online Appendix A that, if the production function is homogeneous, the latter does not occur. (To access the online appendices, see Supporting Information at the end of this paper.) Hence the outcome is one of the four following cases: (1) only the participation constraint of the most remote farmer is binding while the other farmers obtain a positive surplus; (2) only the participation constraint of the first farmer is binding while the other farmers obtain a positive surplus; (3) all constraints are binding and all farmers obtain their reservation income (when $p_M = p - \tau r$ and $i_M = i$); (4) no constraint is binding.

Lemma 1. *Under mill pricing, if the production function is homogeneous of degree $h < 1$, $g(r) \geq 0$ and $g(r + R) \geq 0$ are sufficient to ensure that $g(x) \geq 0$ $\forall x$.*

Proof. See online Appendix A.

Using Lemma 1, the problem can be written as:

$$\max_{p_M, i_M} \Pi = \int_r^{r+R} [(p - \theta r - p_M) f(k^*(x)) + (i_M - i) k^*(x)] dx$$

$$\text{s.t.} \quad g(r) \equiv p_M f(k^*(r)) - i_M k^*(r) - y^0(r) \geq 0$$

and

$$g(r+R) \equiv (p_M - \tau R) f(k^*(r+R)) - i_M k^*(r+R) - y^0(r+R) \geq 0.$$

In Lemma 2, we prove that the case where contract prices are such that only the first farmer's income is pushed down to the reservation level (case (2) above) is dominated by the replication of the stand-alone situation (case (3)). Indeed, in the first case, the intermediary induces all farmers to decrease their production, compared with their stand-alone level, which is not optimal from the intermediary's point of view. Hence, if the first farmer's participation constraint is binding at the optimum, this implies that all participation constraints are binding at the optimum and that $i_M = i$ and $p_M = p - \tau r$.

Lemma 2. *Under mill pricing, if the production function is homogeneous of degree $h < 1$ and $g(r) = 0$ at the optimum, this implies that $g(x) = 0$ at the optimum $\forall x$.*

Proof. See online Appendix B in the Supporting Information (see end of this paper).

6.1 | Model with a specific production function

In what follows, we use a particular production function to derive some characteristics of the optimum.

Assumption 1. $f(k) = 2\sqrt{\mathrm{k}}$.

If the participation constraint of the most remote farmer is binding, this implies that $i_M < i$. If this were not the case, the binding participation constraint would imply that $p_M > p - \tau r$, and this, in turn, would not respect the participation constraint for the other farmers. However, for the unconstrained optimum a priori prices could be such that $i_M > i$ (the farmer loses on the input) and $p_M > p - \tau r$ (the farmer gains on the output) ensuring that no participation constraint is binding. We show that it is not in the interest of the intermediary to set these prices and at the optimum $i_M \leq i$ always holds.

Proposition 3. *Under mill pricing and Assumption 1, the intermediary "loses" on the input trading ($i_M \leq i$) and "gains" on the output trading ($p_M < p - \theta r$).*

Proof. See online Appendix D in the Supporting Information.

Corollary 4. *Under mill pricing and Assumption 1, except in the case where the stand-alone case is replicated, the profit-maximizing contract induces each farmer to increase input use compared with his stand-alone alternative.*

Proof. The participation constraint has to be satisfied for all x. As the production function is homogeneous, this means that $i_M k^*(x) - ik^0(x) \geq 0$ (see also online Appendix A). From Proposition 3, $i_M \leq i$, which implies $k^*(x) \geq k^0(x)$ for the participation constraints to be satisfied. □

This result of farmers increasing their output (also obtained under discriminatory and uniform pricing) is consistent with what is observed in the milk sector in Senegal and in other sectors using interlinked contracts.[11]

Using Lemma 2 and Proposition 3, the Lagrangian can be written as:

$$\begin{aligned} L = & \int_r^{r+R} [(p - \theta r - p_M) f(k^*(x)) + (i_M - i) k^*(x)] dx \\ & + \lambda((p_M - \tau R) f(k^*(r+R)) - i_M k^*(r+R) - y^0(r+R)) + \mu(i - i_M). \end{aligned} \tag{24}$$

Noting that at the optimum $\frac{df}{dk} = \frac{i_M}{p_M - \tau(x-r)}$ and applying the envelope theorem to the farmer's income, the Kuhn–Tucker conditions are:

$$\frac{\partial L}{\partial p_M} = \lambda f(k^*(r+R)) + \int_r^{r+R} \left[\left((p - \theta r - p_M) \frac{i_M}{p_M - \tau(x-r)} + i_M - i \right) \frac{\delta k^*}{\partial p_M} - f(k^*(x)) \right] dx = 0 \tag{25}$$

$$\frac{\partial L}{\partial i_M} = -\lambda k^*(r+R) - \mu + \int \left[\left((p - \theta r - p_M) \frac{i_M}{p_M - \tau(x-r)} + i_M - i \right) \frac{\partial k^*}{\partial i_M} + k^*(x) \right] dx = 0 \tag{26}$$

$$\lambda \geq 0, \quad g(r+R) \geq 0, \quad \lambda g(r+R) = 0 \tag{27}$$

$$\mu \geq 0, \quad i - i_M \geq 0, \quad \mu(i - i_M) = 0. \tag{28}$$

Whether or not the optimum under mill pricing is constrained, depends on the value of the output price p as well as on the importance of the intermediary's cost advantage $\tau - \theta$ compared to the size R of the collection area.

Proposition 4. *Under mill pricing and Assumption 1:*

- *If $\tau r - \theta r > \tau R$ and if the output price is large ($p > \bar{p}$ with $\bar{p}$ unique), then the most remote farmer remains at his stand-alone income ($g(r + R) = 0$) while other farmers obtain a positive surplus from the contract. For a lower output price ($p \in [\underline{p}, \bar{p}]$), all farmers, including the last one, obtain a positive surplus from the contract ($g(x) > 0\ \forall x$).*
- *If $\tau R/2 < \tau r - \theta r \leq \tau R$, then the remote distant farmer remains at his stand-alone income ($g(r + R) = 0$) while other farmers obtain a positive surplus from the contract for all $p > \underline{p}$.*
- *If $\tau R/3 < \tau r - \theta r \leq \tau R/2$ and if the output price is large ($p > \tilde{p}$ with $\tilde{p}$ unique), then all the farmers' incomes remain at their stand-alone level ($\forall x\ g(x) = 0$), hence replicating the stand-alone situation. For a lower output price ($p \in [\underline{p}, \tilde{p}]$), only the most remote farmer remains at his stand-alone income ($g(r + R) = 0$) while the other farmers obtain a positive surplus from the contract.*
- *If $\tau r - \theta r \leq \tau R/3$, then for all $p > \underline{p}$ all farmers remain at their stand-alone income and the stand-alone situation is replicated.*

Proof. See online Appendix E in the Supporting Information.

These results show that under mill pricing the optimal pricing for the intermediary is not always to simply charge farmers the prices they face in a stand-alone situation and to make a profit from the transport cost advantage he has. Depending on the size of the transport cost advantage and the

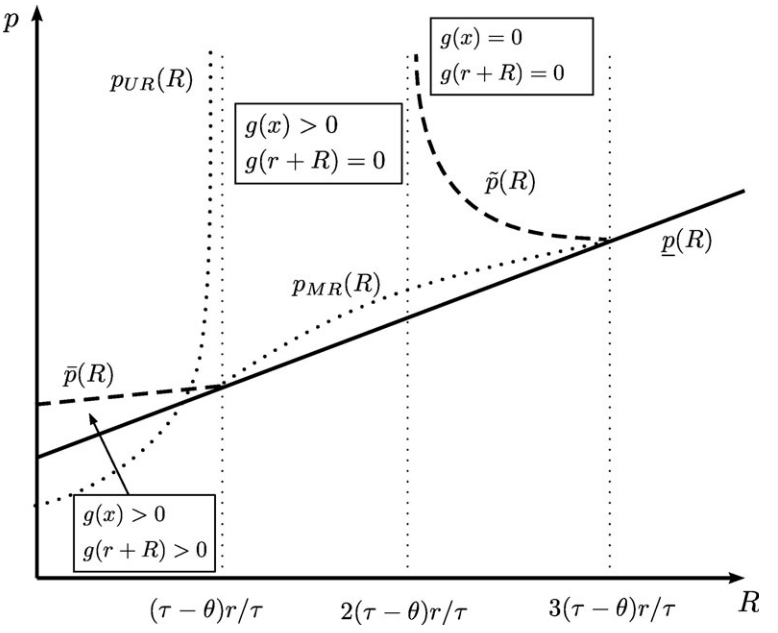

FIGURE 2 Parameter zones

output price, different cases are possible. The different cases for mill pricing are summarized in Figure 2.

If his cost advantage is large enough $(\tau r - \theta r)/\tau > R$, the intermediary uses it to introduce a "distortion" in the prices in order to induce farmers to produce more and hence increase his profit even more. If the intermediary's transport cost advantage is large $((\tau r - \theta r)/\tau > R)$ and the output price is low $(p < \bar{p})$, the optimum is unconstrained, meaning that the contract, which is optimal from the intermediary's point of view, leads to higher incomes for all farmers compared with their stand-alone situation. This is due to the low level of the stand-alone income, which is a consequence of both low output price and high farmer's transport cost. When the output price is larger $(p > \bar{p})$, the outcome is no longer unconstrained: as price p is higher, the transport advantage of the intermediary plays less of a role. The result that with a sufficient transport cost advantage for a low output price all farmers benefit from contracting with the intermediary is interesting in a context where agricultural output prices are driven down by international competition. This means that if international competition drives down prices and if mill pricing is used, all farmers benefit in terms of a higher income from the presence of an intermediary. In contrast, under discrimination or uniform pricing, for any value of p there is always at least one farmer who does not gain.

On the contrary, if the intermediary's transport cost advantage is small $(2(\tau r - \theta r)/\tau < R)$ and if the output price is large $(p > \tilde{p})$, then the contract that would be optimal from the intermediary's point of view would lead to incomes for the farmers that are lower than their stand-alone incomes. Indeed, the high output price leads to large reservation incomes that cannot be compensated by the intermediary's cost advantage as it is too small. In this case, the best the intermediary can do in order for farmers to accept the contract, is to replicate their stand-alone situation.

7 | COMPARISON OF SPATIAL PRICING POLICIES AND IMPACT ON POVERTY

In this section, for each pricing policy, we first establish the optimal size of the catchment area for the intermediary, its impact on farmers' input use and income for each location. We also establish which pricing policy is preferred by the intermediary and the impact of each pricing policy on overall poverty.

7.1 | Optimal size catchment area

In this section we consider a situation where the intermediary chooses the size of its catchment area optimally and compare the outcome under the different spatial pricing policies.

Proposition 5. *Under uniform pricing, the intermediary offers a contract to all farmers only if the rural area is sufficiently small compared with the transport cost advantage. Under mill pricing, the intermediary offers a contract to all farmers only if the rural area is sufficiently small or sufficiently large compared with the transport cost advantage. If this is not the case, the intermediary excludes the farmers located the furthest away. Under discriminatory pricing, the intermediary offers a contract to all farmers. In addition, we have that* $R_U \leq R_M \leq R_D = R$.

Proof. See online Appendix F in the Supporting Information. □

With mill pricing, except for values of R such that $(\tau - \theta)/\tau < R < 3(\tau - \theta)/\tau$, the intermediary offers contracts to all farmers. For intermediate values of R, as illustrated in Figure 2, the intermediary offers contracts to all farmers only if $p \geq p_{MR}(R)$ with $p_{MR}(R) \geq \underline{p}(R)$.

In Figure 2 the curve $p_{UR}(R)$ represents for every value of R the minimum value required for the output price p such that under uniform pricing the intermediary offers contracts to all farmers. This shows that $R_U \leq R_M$. In other words, from the perspective of participation uniform pricing is the least good since it will include all farmers only when the size of the rural area is small compared with the advantage of the transport cost. From that same perspective, mill pricing is better since in several cases it will include all farmers and when it does not, it offers contracts to more farmers than under uniform pricing. Hence, in several cases, more remote farmers, who are also poorer, are offered contracts under mill pricing and not under uniform pricing. Finally, under discriminatory pricing, the intermediary offers contracts to all farmers.

7.2 | Output and incomes

We have shown that, whatever the pricing policy used, the optimal interlinked contract chosen by an intermediary with a sufficient transport cost advantage induces each farmer to increase his input use compared with the stand-alone case. In Figure 3b, we represent farmers' output as a function of distance, under the three pricing policies when $\tau r - \theta r > \tau R$ and $p > \bar{p}$. As can be seen, for all three policies output at each location is larger than in the stand-alone case. Comparing mill and uniform pricing, we can show that under uniform pricing a larger overall quantity is produced compared with mill pricing.

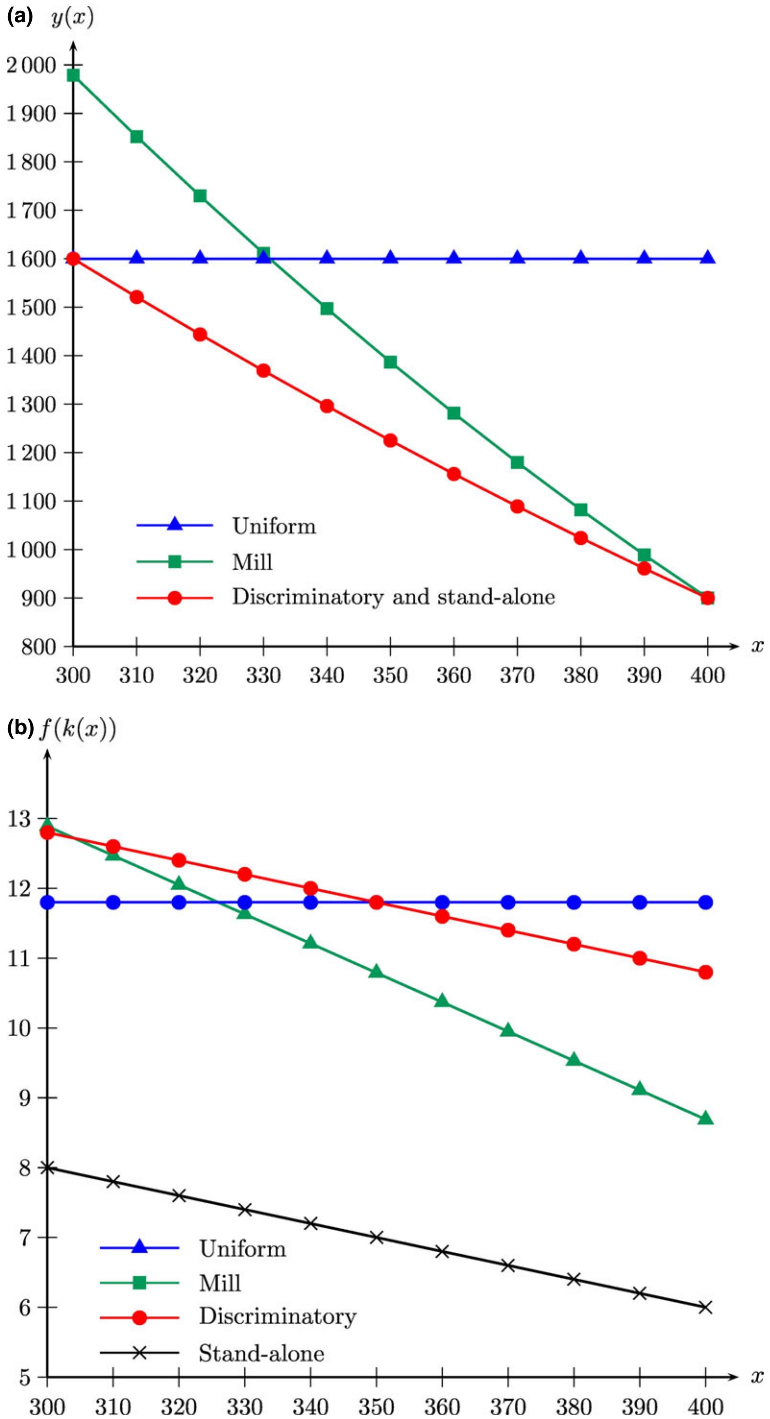

FIGURE 3 (a) Farmer's income $y(x)$; (b) Output produced $f(k(x))$ [Colour figure can be viewed at wileyonlinelibrary.com]

The increase in the production by farmers does not always result into an increase in the farmers' incomes as the gain may be completely acquired by the intermediary. In Figure 3a for the same parameter values as Figure 3b, we represent income in function of distance. With discriminatory pricing, all farmers, even though they produce more, remain at their stand-alone income.

Uniform pricing leads to an increase in income for the poorest farmers, while richer ones are not worse off. Indeed, under this policy, only the farmer closest to the market, that is, the one who has the highest initial income, is not able to increase his revenue. All the others are able to obtain a positive surplus from the contract, and hence to increase their income. Note, however, that this is only possible if the intermediary's transport cost advantage is large enough compared with the size of the collection area. If this advantage is small, uniform pricing does not allow the intermediary to make a positive profit and to exploit his cost advantage to increase production.

If the intermediary has a sufficiently large cost advantage, the use of mill pricing also increases the income of most farmers, but, contrary to the uniform pricing case, farmers far from the intermediary, who were already poor, gain less than the ones close to the intermediary.

Producers' organizations in developing countries and NGOs argue that prices for agricultural goods are too low and claim that they remain low owing to "unfair" international competition caused by subsidized exports from industrialized countries. If output price p is very low, we have shown that the use of mill pricing by an intermediary that has a large cost advantage may result in increasing all farmers' income, including the most distant one.

With spatial price discrimination, farmers do not gain. In Senegal, the use of spatial price discrimination is not observed in the milk sector. For the two other policies our model shows that if the trader's cost advantage is large enough, then there are some farmers who gain relative to the no-contract situation. If the trader's cost advantage is small, then either the trader is not profitable (and does not enter) or can do no better than replicating the no-contract situation.

7.3 | Profit

If discrimination is possible and costless, the for-profit intermediary will choose to discriminate as it leads to the highest profit. In this situation, production is increased. However, no farmer's poverty is reduced, as they all get the same income as in their stand-alone initial situation. While the presence of an intermediary that has a transport cost advantage is beneficial from the point of view of increasing production, it is not from a poverty reduction one.

Figure 4 shows, in the case where the rural area is small compared to the cost advantage of the intermediary, how the level of profit for the different pricing policies changes when output price p varies.

Not surprisingly, for all three spatial pricing policies, the profit is increasing in output price p. Not surprisingly either, price discrimination dominates the two other pricing policies. The ranking between mill and uniform pricing depends on the level of the output price: the intermediary prefers uniform pricing when the price is low and mill pricing when it is high. If the intermediary's cost advantage is small, the use of uniform pricing will result in a negative profit. Under mill pricing and discriminatory pricing, however, the intermediary is able to contract profitably with all farmers, whatever the level of cost advantage.

For both mill and uniform pricing the intermediary gains in terms of the output trading and loses in terms of the input trading. As the overall quantity produced under uniform pricing is larger than under mill pricing the gain for output trading is larger for uniform pricing and the loss from input trading is also larger. In addition, the intermediary bears the transport costs. The transport costs increase with price p (as the output increases) and with the size of the collection area. For low prices p and a small collection area, the transport costs are low and smaller than the difference between mill and uniform pricing in terms of output and input trading. The conclusion is that the profit that can be obtained from uniform pricing is larger than under mill pricing in that case, but

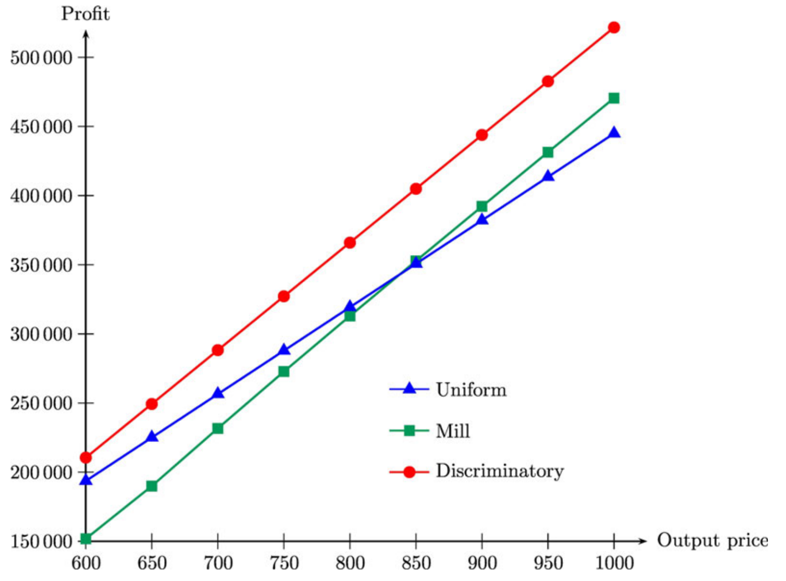

FIGURE 4 Comparison of spatial pricing policies in terms of profit [Colour figure can be viewed at wileyonlinelibrary.com]

as the price p is higher and/or the collection area is larger, the transport costs increase and the gains from input and output trading are no longer sufficient to cover these transport costs. As a consequence, for those cases mill pricing profit is higher than uniform pricing profit for all values of p.

7.4 | Poverty

As the farmers are geographically dispersed, they are affected differently by the different pricing policies. To establish which pricing policy performs better in reducing poverty, we compare the outcomes of the different pricing policies in terms of the poverty indicator proposed in Foster, Greer, and Thorbecke (1984):

$$\mathrm{Pov}_\alpha = \frac{1}{\bar{R}} \int_{r+R_Z}^{r+R} \left(\frac{z - y(x)}{z} \right)^\alpha dx \tag{29}$$

where $z > 0$ is the poverty line, R_z is defined by $y(R_z) = z$ and α can be seen as a measure of poverty aversion, a larger α giving greater emphasis to the poorest farmers. The number of poor farmers (who have an income lower than z) is given by R - R_z. The larger is Pov_α, the higher is the poverty.

As measured by Pov_α, spatial price discrimination does not reduce poverty, because it does not increase farmers' incomes. The ranking of the Pov_α index for all the pricing policies depends on the values of the different parameters. Here we give a certain number of illustrations of different cases. Using different numerical values for the parameters, we show that for small values of R mill pricing tends to perform better in reducing poverty for low values of p while uniform pricing dominates when the output price is larger (see Figure 5).

When the size of the rural area is larger, the difference between uniform and mill pricing is that more farmers are included with mill pricing. The consequence is that over the segment where under both pricing policies the farmers are included we have $\mathrm{Pov}_\alpha^U < \mathrm{Pov}_\alpha^M$, while over the segment where farmers are included only under mill pricing we have $\mathrm{Pov}_\alpha^U > \mathrm{Pov}_\alpha^M$. For the index over the whole rural area for low values of p we have $\mathrm{Pov}_\alpha^U < \mathrm{Pov}_\alpha^M$, while for high values of p we have

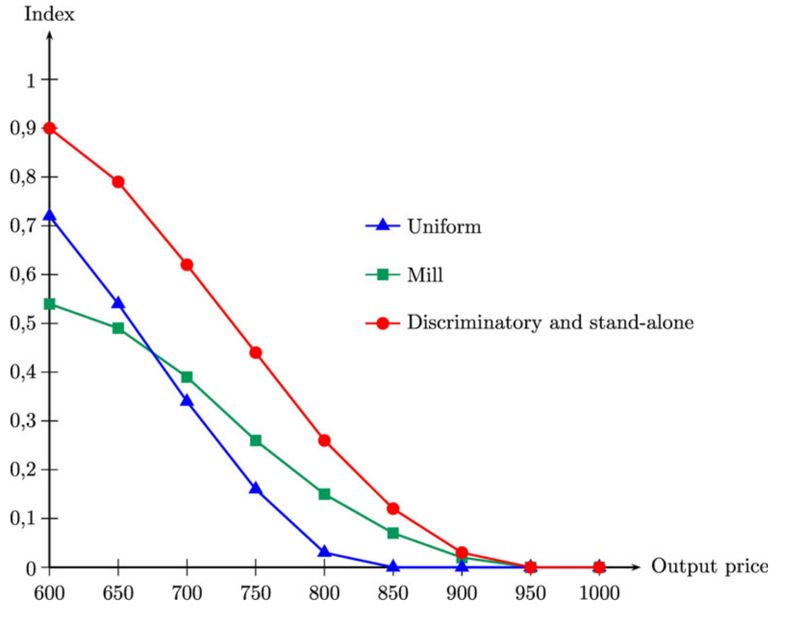

FIGURE 5 Comparison of spatial pricing policies in terms of poverty [Colour figure can be viewed at wileyonlinelibrary.com]

$\text{Pov}_\alpha^U > \text{Pov}_\alpha^M$. For large values of R we have $\text{Pov}_\alpha^U > \text{Pov}_\alpha^M$ for all values of p. When mill pricing replicates the standalone situation, we have $\text{Pov}_\alpha^U \leq \text{Pov}_\alpha^M$, with a strict inequality sign if $R_U > Rz$. This will be the case when output price p is low and z is high.

The question that remains is whether the intermediary chooses the pricing policy that is optimal from the point of view of poverty reduction. Using the information about the effect of the pricing policies on the profit and the FGT index we arrive at the following conclusions. For small values of R when p is low, the intermediary prefers uniform pricing while mill pricing leads to the lowest level of poverty. When p is high, we have the opposite result: mill pricing is preferred by the intermediary while it is uniform pricing that is the best in terms of poverty reduction. Hence only in the case of intermediate values of p will the intermediary choose the pricing policy that is also the optimal policy in terms of poverty reduction. For intermediate values of R the intermediary chooses the pricing policy that also reduces poverty the most. For the standalone case, mill pricing is preferred by the intermediary while in terms of poverty uniform pricing weakly dominates.

8 | CONCLUSIONS

In this paper, we develop a model of input–output interlinked contracts between an intermediary and geographically dispersed farmers, and analyze the implications of different spatial pricing policies used by this intermediary. We look at three different spatial price policies, namely spatial price discrimination, uniform pricing, and mill pricing.

We assume an agricultural output market that is characterized by large transport costs. The intermediary has a (transport) cost advantage over the farmers from whom it buys their production. This cost difference leads to an input–output interlinked contract between the intermediary and the farmer. One result is that the use of an interlinked contract by an intermediary that has a sufficient transport cost advantage leads to an increase of the farmer' production, independently of the type of pricing policy used by the intermediary.

If the for-profit intermediary is able to perfectly discriminate contracts between farmers, this would be his preferred option. This allows him to keep all the farmers' incomes at their stand-alone income and hence appropriate all the efficiency gain generated by the contract. If this is the case, the presence of the intermediary, while improving agricultural efficiency, does not directly help to reduce rural farmers' poverty. In practice discriminatory pricing might not be feasible and other pricing policies exist, such as uniform pricing or mill pricing. If the intermediary's cost advantage is large enough, we show that in both cases, most farmers obtain a positive surplus from the contract, while the intermediary is still able to make a profit. In the mill pricing case, when output price p is low we can have a situation in which all farmers, including those located the furthest from the market, see an increase in their income. If agricultural market prices are driven down by international competition, mill pricing by the intermediary would be the most favorable choice for the farmers. If the transport cost advantage is small, with uniform pricing the intermediary would not be able to make a profit by offering contracts to all farmers while with mill pricing it could still make a positive profit. Even if it decides to exclude the most distant farmers it would still offer a contract to more farmers under mill than under uniform pricing. If the transport cost advantage is very small, under mill pricing the best the intermediary can is to replicate the no-contract situation. This means that if the intermediary is not price discriminating, with a large cost advantage some farmers will benefit from the presence of an intermediary while with a small cost advantage either the intermediary does not enter (because it would make losses) or simply replicates the no-contract situation.

We measure the impact of each spatial pricing policy by using the Foster–Greer–Thorbecke index. As with discriminatory pricing the incomes of farmers remain unchanged, this pricing policy does not contribute to poverty reduction. For the two other pricing policies, the ranking depends on the size of the rural area with respect to the transport cost advantage and the output price. For a small rural area and a low output price, mill pricing performs better than uniform pricing while the opposite is true when the output price is high. For larger rural areas, uniform pricing includes fewer farmers than mill pricing and hence contributes less to poverty reduction. For very large rural areas, uniform pricing weakly dominates mill pricing as in this case the no-contract situation is replicated.

Price discrimination leads to the highest profit. For the two other policies, the ranking in terms of profit for the intermediary depends on the different parameters. For a low output price, the intermediary would prefer uniform pricing while it would choose mill pricing for higher prices.

We show that for small rural areas and either low or high output prices there is a mismatch between the objective of profit-maximizing and poverty reduction as the optimal spatial pricing policies would be different in each case. For larger rural areas, this is not a problem. Hence when there is a mismatch between the two objectives, ideally the state should impose the spatial pricing policy. We show that the optimal poverty reducing pricing policy is not necessarily uniform pricing. However, in developing countries, the enforcement of these pricing policies might be difficult.

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ENDNOTES

[1] Often the transport cost for the input is effectively zero as it is purchased when the output is delivered.

[2] By locating just outside of a rural area, the intermediary has a better access to roads to urban centers, electricity, water, etc. Because of the limited number of farmers involved and the potentially large fixed investment costs, further entry would unlikely be profitable.

[3] By rewriting the model slightly, we can interpret our framework as a situation in which an intermediary is able to charge a higher price than the farmer for a (transformed) product.

[4] Reasons for the emergence of interlinked transactions are: rationed or imperfect rural credit, output market price uncertainty, risk aversion, and unobservable tenant effort.

[5] In Section 7 we establish for each pricing policy i the optimal size of the collection area, and whether it is optimal to include all farmers, that is, $R_i = R$, or to exclude some farmers, that is, $R_i < R$.

[6] As the examples of Section 2, we focus on linear contracts. One of the reasons explaining the absence of nonlinear contracts could be that in the presence of nonlinear prices farmers could collude to game the scheme for example by selling their milk quantities together. See also Ray (1998).

[7] F can represent, for example, the cost of refrigerated trucks to transport transformed milk to markets, machines to sterilize milk, or pick-up trucks to collect milk from farmers. Hereafter, we omit F assuming that it is not too high for the intermediary while too high for a single farmer.

[8] In Kenya both British American Tobacco and Kenya Tea Development Agency deliver input to farmers at prices that are lower than wholesale prices (IFAD, 2003). Sometimes, input is even given for free (Koo, Huang, & Kan, 2012).

[9] In other contexts Warning and Key (2002) for Senegalese peanut producers and Simmons et al. (2005) for seed corn in East Java and for broilers in Lombok have found that contracts increase producers' incomes.

[10] This is obviously satisfied if the intermediary chooses optimally R. See online Appendix F in the Supporting Information.

[11] For example, in the Indian poultry sector (Ramaswami, Birthal, & Joshi, 2009) and in Ethiopia, for haricot bean producers (Tadesse & Guttormsen, 2009).

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SUPPORTING INFORMATION

Additional Supporting Information may be found online in the supporting information tab for this article.

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