An Analysis of Partially-Guaranteed-Price Contracts between Farmers and Agri-Food Companies

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March 6, 2016

Abstract

Global agri-food companies such as Barilla and SABMiller are purchasing agricultural products directly from farmers using different types of contracts to ensure stable supply. We examine one such contract with partially-guaranteed prices (PGP). Under a PGP contract, around sowing time, the buying firm agrees to purchase the crop when harvested by the farmer, offering a guaranteed unit price for any fraction of the produce and offering the commodity market price prevailing at the time of delivery for the remainder. The farmer then chooses the fraction. By analyzing a Stackelberg game, we show (1) how the PGP contract creates mutual benefits when the firm's purchase quantity is taken as being exogenous. We also analyze how the PGP contract is robust in creating value for both the firm and the farmer (2) when the firm's purchase quantity is endogenously determined; (3) when the firm provides advisory services to the farmer; and (4) when the firm offers a price premium as an incentive for farmers to exert efforts to comply with 'sustainable' agricultural practices.

Keywords: Buyer-seller contracts; sustainability; agriculture; Stackelberg game; agri-food.

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1 Introduction

Farmers in both developing and developed countries face huge and possibly growing price uncertainty. For instance, the price of Arabica coffee price hit record price at over US$3 per pound in 2011, dropped to US$1 per pound in 2013 and then rebounded to US$1.80 by the of May in 2014 (Josephs, 2013; 2014; also Danby and Sellen 2010). When the wheat price surged at end 2007, many farmers in the Emilia Romagna region of Italy focused on growing durum wheat (Formentini et al. 2014). However, when the price of wheat collapsed in 2009, many farmers began to move away from wheat cultivation. Similarly, in 2015, many Chinese dairy farmers poured away milk and slaughtered cows as milk prices collapsed after the boom two years earlier (Yap, 2015). Dealing with price risk faced by farmers is therefore an important issue (cf. Broll et al. 2013).

Contract farming is growing as a way to mitigate demand uncertainty for the farmer and supply uncertainty for the buyers as well as a way to improve traceability in the supply chain (cf. Aiello et al. 2015; see Belavina and Girotra 2015 for relationship sourcing in general). Agri-food firms including manufacturers and retailers are increasingly purchasing directly from farmers to reduce risk and improve returns for both sides. Some of these firms also provide advisory services to farmers. One such company, Barilla, uses a particular type of contract with farmers, which we call the *Partially-Guaranteed-Price (PGP) contract* (Formentini et al. 2014); beverages giant SABMiller also has similar purchasing contracts.

This paper analyzes how such direct purchase contracts create value for the firm and the farmer. We assume the familiar setting of a buyer-seller contract between a risk-neutral buyer, i.e., the agri-food company, and a risk-averse supplier, i.e., the farmer who is typically but not always a smallholder. Under the basic PGP contract, around sowing time, the buying firm agrees to purchase the entire crop q harvested by the farmer (who has already set the production quantity in advance of signing such contracts). The firm offers a guaranteed unit price g for any proportion of his crop with the remaining quantity priced at the market price prevailing at the time of delivery; the farmer then selects this proportion α as part of the contract.

Our analysis shows that (1) the PGP contract creates extra supply chain surplus for the farmer as well as for the buying firm relative to simply using the market; this result continues to hold when the buying firm imposes an upper bound on α or when the farmer can set his production quantity q in anticipation of the PGP contract. Furthermore, we analyze the PGP contract in a variety of settings arising from practice, including: (2) when the firm's purchase quantity y is *endogenously* determined; (3) when the firm provides advisory services to the farmer; and (4) when the firm offers a price premium as an incentive for farmers to exert efforts to comply with certain sustainable agricultural practices. Thus, our analysis provides an economic rationale for agri-food firms like Barilla and SABMiller offering PGP contracts as well as advisory services to farmers. We show how the well-understood dynamics between risk-averse sellers and risk-neutral buyers play out in the agri-food domain, and with mutual benefits that are robust across a variety of extensions in practice.

Our paper primarily contributes to the emerging literature on *socially responsible operations* (Zhou and Tang, 2012; Sodhi and Tang 2014; and Sodhi 2015) especially regarding large agri-food firms buying directly from farmers. Examples are Indian FMCG company, ITC, buying soya bean from farmers (cf. Devalkar et al. 2011), Nestle buying coffee beans (Alvarez et al. 2010), Starbucks buying coffee beans (Lee et al., 2013; 2007) and Walmart buying fruits and vegetables (Yeh and Tang 2013). The agri-food sector in general (cf. Ahumada and Villalobos, 2009) and contract farming in the developing world in particular is gaining considerable interest (Goyal 2010). There is also a strand focusing on advisory services provided to the farmer by third parties (Berdegue and Marchant 2002; Swanson 2008; Gakuru et al. 2009; Fafchamps and Minten 2012; and Tang et al. 2014). Our paper contributes in three ways: (1) Purchasing is essentially transactional in this literature whereas we describe and analyze contracts (see Belavina and Girotra 2015 for relational sourcing); (2) to our knowledge, not much analytical work has been carried out in the extant literature – Pagell and Shevchenko (2014) underscore the need for analytical modeling in such contexts. Our paper is a step towards meeting this need; (3) the literature thus far has not considered the use of advisory services contractually as part of contract farming as we do with PGP contracts.

The rest of the paper is organized as follows: In Section 2, we provide motivation and background based on Barilla. Section 3 provides the basic setup for our model for the case when the firm purchases directly from the farmer without partial guaranteed prices (i.e., without PGP). Section 4 presents the analysis of the basic PGP contract for the case when the purchase quantity is exogenously given. Section 5 generalizes the basic PGP contract for the case when the firm's purchase quantity is endogenously determined. In Section 6, we extend the model of the basic PGP contract to the case when the firm offers advisory services to the farmer as part of the contract. In Section 7, we discuss the firm offering an incentive to the farmer to comply with sustainable agricultural practices. We conclude with some areas for further research in Section 8. All proofs are provided in the Appendix.

2 Motivation and Background

Examples of agri-food firms buying directly from farmers (as opposed to only from commodity markets) include Barilla's 'Good for you, good for the planet' initiatives, Nestlé's 'Creating Shared Value' programs, Starbucks' 'C.A.F.E.' initiative and Walmart's 'Direct Farm' initiative (Lee et al. 2013, 2015; Lee 2007; Yeh and Tang 2013). Moreover, many global agri-food companies offer agricultural advisory services to farmers from whom they purchase especially in developing countries. For instance, under its "creating shared value" initiative, Nestlé works with coffee farmers to help them to reduce production cost by improving their farming techniques. In the Sawi area of Thailand, Nestlé's agronomists teach farmers how to reduce the cost of fertilizers by using compost and drip irrigation. Nestlé also teaches coffee farmers how to manage soil quality and pest control in an environmentally sustainable manner (Lee et al. 2013; 2015). In Italy, Barilla provides advisory services (e.g., weather forecast, phenology, seeding, crop development, fertilization, weeding, pesticides, herbicides) to farmers to help them to reduce cost, increase yield, and reduce carbon footprint.

Barilla uses PGP contracts with farmers as described in the previous section. SABMiller uses a similar contract in Africa by agreeing to contract a certain quantity of sorghum in Africa from the smallholder farmer (or a collective) during the sowing season at a guaranteed unit price. The farmer then decides the fraction of his expected produce to pre-sell to SABMiller at this price, with the remainder to be sold to SABMiller or in the open market at the market price after harvest (Bariyo and Evans, 2015). In practice, these contracts have add-on requirements and incentives. For example, the PGP contracts adopted by Barilla come with incentives and/or price premiums for the farmer following 'sustainable' agricultural practices. Starbucks' 'C.A.F.E.' initiative offers similar incentives (Lee, 2007).

For the Italian market, Barilla used to purchase most of its durum wheat from Italy and small quantities from other European countries such as France, Greece, and Spain. Unfortunately, due to stagnant market price of wheat from 1990 to 2006, many Italian farmers stopped growing durum wheat. For instance, after a peak in wheat production in Emilia Romagna in 1991 with 490,000 tons, the overall production in that region fell below 100,000 tons in 2006, an 80% drop from the peak). As local supply dropped, Barilla had to increase its purchase from the international wheat market, especially from North America, to meet its sales in the Italian market. In 2013 and 2014, we conducted interviews with Barilla's purchasing managers to learn of Barilla's contracts, and with consortium managers representing farmers to understand farmers' decisions and behavior. We refer the reader to Formentini et al. (2014) for details.

Although Barilla could obtain sufficient supply of durum wheat internationally from, say, Arizona, there are concerns regarding transportation cost, carbon and water footprint, as well as regarding quality requirements on the wheat being free from GMO and having high percentage of protein. To sustain stable supply of high quality durum wheat at stable price and to encourage sustainable agricultural practices, the local government, farmer consortia and Barilla decided to work together by using incentive contracts.

In the first direct purchase contract signed in 2006, Barilla committed to purchase 30,000 tons of durum wheat from the contract farmers. This contract reduced the farmer's quantity risk and enabled Barilla to secure more supply of wheat in the local region. The basic contract price was primarily based on the local commodity market, Borsa Merci di Bologna. The durum wheat price shot up in 2007 followed by a sharp drop in 2008, forcing some farmers to exit the wheat market. In line with its strategy to procure more wheat domestically for pasta sold in the Italian market, Barilla established a new contract with the farmers to purchase 60,000 tons of durum wheat in 2009. Under the new contract, the contract price was based on the market price plus a guaranteed additional price premium as an incentive.

Recognizing the fact in 2009 that the guaranteed price premium essentially transferred all the price risk to Barilla, the firm established the PGP contract.

Under the PGP contract in 2010, Barilla committed to purchase 80,000 metric tons of wheat. As part of the contract, Barilla offered a guaranteed purchase price that is known to the farmer during the sowing season (i.e., after the production quantity has already been determined by the farmer in advance). In return, the farmer could choose the percentage of the purchase quantity α to be priced at the guaranteed price and the rest $(1-\alpha)$ priced at the market price prevailing upon delivery after harvest. The PGP contract reduced price risk for the farmers. However, to limit its exposure to price risk, Barilla imposed an upper limit each year on α so that $\alpha \leq 0.3$, say. We also learned from the representative from a farmers' consortium that the farmers would like Barilla to lift the upper limit to a higher level, thus revealing their risk aversion. As a result, how to approach imposing an upper limit, if any, on α is an open policy question within the company.

In 2013, pursuing "Good for you, good for the planet" corporate goals, Barilla extended the PGP contract by offering additional premium of 30 Euros per ton if farmers adhered to the guidelines for sustainable agricultural practices as specified by the web-based decision support system GranoDuro (www.granoduro.net). By the end of 2014, 30% of the quantity purchased from the farmers was produced according to these guidelines, and the company hopes to achieve 100 percent compliance by 2020.

Barilla's contracts have provided enough incentives for farmers to increase their wheat production since 2006. By the end of 2012, Barilla managed to source 70% of its durum wheat from Italy itself for the Italian market. As a result of this successful implementation of the PGP contract and incentive for farmers to adopt sustainable agricultural practices, Barilla has also managed to reduce its carbon footprint by 30%, reduce farmer's production cost by 30% and increase farmer's production yield by 20%. In recognition of its efforts, Barilla won the European CSR Award in 2013.

We seek to understand how PGP contracts with incentives and compliance requirements help farmers and buying firms like Barilla.

3 Model Preliminaries: Direct Purchase without PGP

Consider a farmer growing two crops with unit cost c, one with a price that is known at the time of sowing to be k upon delivery after harvest and the other with a price that is currently uncertain upon delivery. This latter crop (e.g., durum wheat for Barilla or sorghum for SABMiller) has an (ex-ante) uncertain market price P that will become known after harvest, where $P \sim N(\mu, \sigma^2)$.[1] Faced with an uncertain market price, the risk-averse farmer has to allocate land to either crop given his limited production capacity. Here, we consider the case that the farmer sets his production quantity based on the assumption that he will sell his entire crop in the open market and he does not know and will not anticipate any buyer will offer any direct purchase contract (e.g., PGP contract).

3.1 The Overall Sequence of Decisions

Although this section is about direct purchase *without* PGP contracts, it would be worthwhile to look at the overall contract process to understand the sequence of decisions (Figure 1):

1. At the beginning of the sowing season, the farmer evaluates the economic tradeoff between two alternative crops and decides to produce q units for the crop that has an ex-ante uncertain unit price P and produce $(\text{cap} - q)$ units for the other crop that with a stable unit price k. Essentially, the farmer sets his production quantity q by assuming that the crop will be sold in the open market. In other words, we assume that the farmer does not know and cannot anticipate a buyer will offer a direct purchase contract (e.g., the PGP contract) at this point in time.

2. Upon observing the farmer's production quantity q, the firm agrees to purchase $y = q$ units from the farmer with the remaining $(r - q)$ units to be purchased from the open market . At the same time, the firm offers the farmer a *guaranteed* unit price g. Hence, the buyer will pay the farmer g per unit regardless of the realized market price so that the farmer wins (loses) if g is above (below) the realized market price. Also,

[1] For tractability, it is commonly assumed that the market price P is normally distributed in the research literature. Examples include Chen and Tang (2015) and the references therein. Also, the normal distribution is a reasonable assumption because the market price forecast is often derived from linear regression models so that μ is the forecasted price and σ^2 represents the forecasting error.

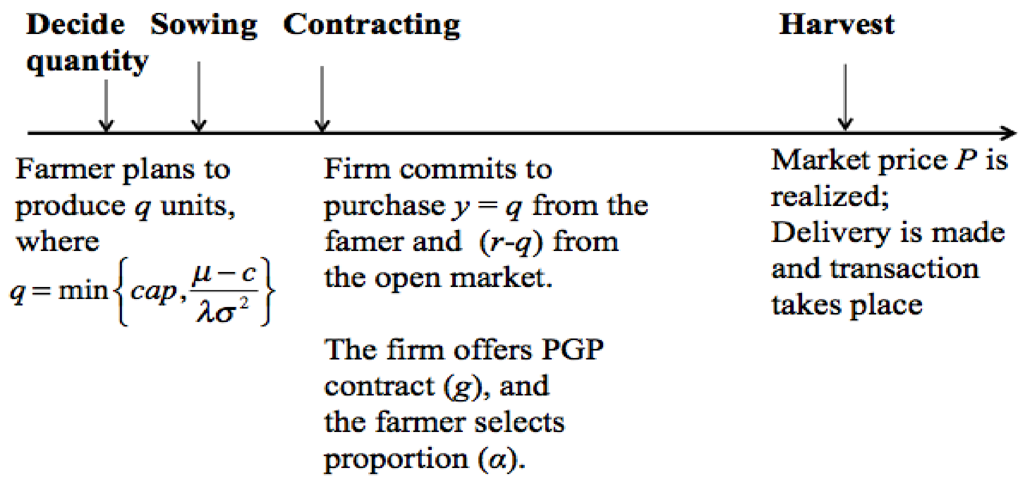

Figure 1: Timing associated with the PGP contract

the contract between Barilla and the farmer is overseen by the local government to ensure compliance by both parties. In the long run, it could be argued that these contracts are self-enforcing (cf. Kvaløy 2006). Under the direct PGP contract, the farming process is tightly controlled by Barilla (which fertilizer and pesticide to use). As such, there is little yield uncertainty and the farmer can effectively deliver q to the buyer. Nevertheless, yield uncertainty can be important in other settings and worth investigating as part of future research.

3. Given the guaranteed unit price g, the farmer selects the proportion α so that the effective (ex-ante) unit selling price would be equal to $\alpha g + (1-\alpha)P$. As mentioned in Section 2, the buying firm may impose an upper limit on α to control the amount of price risk the firm is willing to absorb from the farmer. For instance, Barilla imposed an upper limit at 30% under its PGP contract in one year. Here we initially allow $\alpha \in [0, 1]$ and deal with $\alpha \leq b]$ for an upper limit as an extension, e.g., with $b = 0.3$.

4. After the harvest season, the market price P is realized and the payoff to each party is determined accordingly.

3.2 Farmer's Decision on Production Quantity q

We assume the farmer first decides on allocating land across these two different crops, of which the one with uncertain price is the commodity of interest for PGP contracts. In our motivating example, Barilla is not obligated to offer any direct purchase contract and continues to purchase in international commodity markets even for pasta for the Italian market. As such, it is reasonable to assume that farmer plans his production quantity with the intention to sell their crop in the open market. In other words, when deciding on their production quantities, farmers do not know and will not anticipate a buyer will offer any direct purchase contract. An alternative assumption could have been that contract negotiations take place prior to the allocation decision so the farmer would know the effective price for both crops. In the present context, however, the farmer makes the crop allocation decision prior to any contract negotiations so that is the assumption we make here.

Given a production capacity of cap, the farmer produces x units of the crop that has an uncertain market price P and $(\text{cap} - x)$ units of the crop that has a certain market price k. The farmer will obtain an expected utility

$$E[U(f(P))] = E(1 - exp[-\lambda\{(P-c)x + (k-c)(\text{cap} - x)\}])$$

where $\lambda > 0$ is the absolute risk averse factor that measures the degrees of risk-aversion of the farmer and c is the unit production cost. Because $P \sim N(\mu, \sigma^2)$, we have

$$E[U(f(P))] = 1 - exp[-\lambda(\mu - c)x - \lambda(k-c)(\text{cap} - x) + (\lambda^2 x^2 \sigma^2)/2]$$

Hence, the *certainty equivalence* of the farmer's expected utility is

$$\pi_f^0(x) = (\mu - c)x + (k-c)(\text{cap} - x) - \frac{\lambda}{2}x^2\sigma^2.$$

In this case, the farmer's optimal production quantity $q = \text{argmax}\{\pi_f^0(x) : x \leq \text{cap}\}$. By considering the first-order condition, the farmer's optimal production quantity q satisfies:

$$q = \min\left\{\text{cap}, \frac{\mu - k}{\lambda\sigma^2}\right\} \tag{1}$$

where q captures the tradeoff between producing the crop with stable price and the crop with uncertain price. (Note that $q = 0$ if $\mu \leq k$. Hence, it suffices to focus on the case when $\mu > k$

so that $q > 0$.) Also, the *certainty equivalence* of the farmer's expected utility for selling q units to the firm without PGP is equal to π_f^0, where $\pi_f^0 = (\mu - c)q + (k - c)(\text{cap} - q) - \frac{\lambda}{2}q^2\sigma^2$. For ease of exposition, we can scale the margin $(k - c)$ to 0 without loss of generality so that the farmer's certainty equivalence can be simplified as:

$$\pi_f^0 = (\mu - c)q - \frac{\lambda}{2}q^2\sigma^2 \tag{2}$$

with quantity

$$q = \min\left\{\text{cap}, \frac{\mu - c}{\lambda\sigma^2}\right\}.$$

3.3 Buying Firm's Purchase Quantity y

Given the farmer's (optimal) production quantity q given in (1) that is based on the assumption that the farmer did not know or anticipate the buying firm will offer a direct purchase contract, how much should the firm purchase directly from this farmer?[2] Here we consider that the buying firm uses planning models to determine its requirement of r units over its planning horizon (cf. Ahumuda and Villalobos, 2009). Because the firm is a large multinational company, it is reasonable to focus our analysis on the case when $q < r$, i.e., the farmer(s) can provide less than the company's requirements.[3]

3.4 Base Model

Knowing its requirement r and the farmer's quantity q, the firm has to decide on the purchase quantity y from the farmer, with $y \leq q$. For ease of exposition, we first examine in Section 4 the case where the purchase quantity y is taken *exogenously* to be $y = q$. Later, in Section 5, we shall relax this assumption to the case where the purchase quantity y is determined *endogenously* as a decision variable with $y \leq q$.

In the base case, we consider the case when the firm purchases $y = q$ units from the farmer and the remainder $(r - q)$ from the open market. In this case, its expected cost is: [4]

$$\pi_b^0 \quad = \quad \mu q + \mu(r - q) = \mu r. \tag{3}$$

[2] The question is more meaningful when the firm is negotiating with a consortium or cooperative or farmers. In Barilla's case, the farmers communicate their equivalent of q.

[3] It can also be shown that the PGP contract will create and share value between the firm and the farmer even when $r \leq q$.

[4] Although there are taxes and/or commissions to intermediaries for facilitating the transactions between

When the firm offers direct purchase contracts without PGP, the farmer can eliminate his quantity risk but faces the risk of price uncertainty. Specifically, the farmer may effectively abandon this particular crop by setting $q \approx 0$ when the price uncertainty σ^2 becomes large. To ensure stable supply, the firm may need to offer the PGP contract to reduce the farmer's price risk (in addition to the pre-committed purchase quantity as stipulated in the direct purchase contract). This observation motivates the following question: Will the PGP contract benefit the farmer, the firm or both? We investigate this in the following section.

4 PGP Contract with Exogenous Purchase Quantity

We now examine the PGP contract for the case when the firm decides to purchase $y = q$ units from the farmer and purchase the remainder $(r - q)$ from the open market, where the production quantity q has already been decided by the farmer in advance without anticipating the PGP contract.[5] At the same time, the firm opens negotiations on a PGP contract.

4.1 No Upper Bound on α

We model the interaction between the firm and the farmer as a Stackelberg game and solve it via backward induction. Specifically, the firm is the leader selecting g to minimize its expected cost and the farmer is the follower choosing the proportion α to maximize his certainty equivalence. In this base model, we consider the case when the buying firm does not impose an upper bound on α.

For any given guaranteed price g, the farmer chooses α that maximizes his certainty equivalence. By considering the fact that farmer's profit equals $[\alpha g + (1-\alpha)P - c]q$, that $E(\alpha g + (1-\alpha)P) = (\alpha g + (1-\alpha)\mu)$, and that $V(\alpha g + (1-\alpha)P) = (1-\alpha)^2\sigma^2$, the farmer's problem can be formulated as:

$$\pi_f(g) \quad = \quad \max_{\alpha \in [0,1]} \quad [\alpha g + (1-\alpha)\mu - c]\, q - \frac{\lambda}{2}(1-\alpha)^2 q^2 \sigma^2, \tag{4}$$

the firm and the farmer or for aggregating the farmers' produce, we ignore these transaction costs for ease of exposition. However, our analysis and the result would continue to hold even if we were to incorporate these commissions.

[5] We shall extend our based model to the case when the farmer sets his production quantity q in anticipation of the PGP contract, and we shall show that the PGP contract continues to be mutually beneficial. The authors thank two anonymous reviewers for suggesting this extension.

where the optimal proportion $\alpha^*(g)$ satisfies:

$$\alpha^*(g) \;=\; 1 - \left(\frac{\mu - g}{\lambda\sigma^2}\right)\frac{1}{q}. \tag{5}$$

We make three observations from (5). *First*, the optimal proportion $\alpha^*(g)$ increases in the guaranteed price g, the firm's purchase quantity q, and the price variance σ^2. *Second*, the farmer will set his proportion $\alpha^*(g) = 1$ when the guaranteed price $g \geq \mu$ and $\alpha^*(g) = 0$ when $g \leq \mu - \lambda\sigma^2 q$. The firm is interested in minimizing its purchasing cost so there is no incentive for the firm to offer $g > \mu$. Also, the firm is interested in enticing the farmer to accept the PGP contract so that there is no incentive to set $g < \mu - \lambda\sigma^2 q$. Therefore, it suffices to consider the case when $g \in [\mu - \lambda\sigma^2 q, \mu]$. *Finally*, the farmer will participate in the PGP contract only if he is better off relative to the case without PGP. In other words, the participation constraint $\pi_f(g) \geq \pi_f^0$ for the farmer must be satisfied, where $\pi_f(g)$ is given in (4) and π_f^0 is given in (2). We state this as:

Lemma 1 *When the guaranteed price $g \in [\mu - \lambda\sigma^2 q, \mu]$, the participation constraint $\pi_f(g) \geq \pi_f^0$ is satisfied.*

A proof for this lemma and as well as proofs of subsequent propositions are provided in the Appendix. Anticipating farmer's participation (Lemma 1) and farmer's response $\alpha^*(g)$ as stated in (5), the firm determines g^* that minimizes its expected cost as follows:

$$\pi_b \;=\; \min_{g \in [\mu - \lambda\sigma^2 q, \mu]} \;\; [\alpha^*(g)g + \{1 - \alpha^*(g)\}\mu]\, q + \mu(r - q) \tag{6}$$

By substituting $\alpha^*(g)$ given in (5) and by considering the first order condition, it is easy to check that the optimal guaranteed price g^* satisfies:

$$g^* \;=\; \mu - \frac{\lambda}{2}\sigma^2 q. \tag{7}$$

Also, notice that g^* is feasible because $g^* \in [\mu - \lambda\sigma^2 q, \mu]$.

Being risk averse, the farmer is willing to accept the guaranteed price $g^* < \mu$, which is below the expected market price. Substituting g^* into (4), (5) and (6), we obtain:

Proposition 1 *Under the PGP contract, the buying firm will set its guaranteed price $g^* = \mu - \frac{\lambda}{2}\sigma^2 q$ and the farmer will select his proportion $\alpha^* = \frac{1}{2}$ in equilibrium. The farmer's certainty equivalence $\pi_f^* = (\mu - c)q - \frac{3\lambda}{8}\sigma^2 q^2$, and the firm's expected cost $\pi_b^* = \mu r - \frac{\lambda}{4}\sigma^2 q^2$.*

Comparing the farmer's certainty equivalence and the firm's expected cost under the guaranteed price contract with the case when the firm and the farmer engage in the direct purchase contract without PGP as presented in Section 2, we get

Corollary 1 *The PGP contract is mutually beneficial: the farmer will increase his expected certainty equivalence by* $\pi_f^* - \pi_f^0 = \frac{\lambda}{8}\sigma^2 q^2 > 0$ *and the firm will reduce its expected cost by* $\frac{\lambda}{4}\sigma^2 q^2$ *as* $\pi_b^* - \pi_b^0 = -\frac{\lambda}{4}\sigma^2 q^2 < 0$.

Corollary 1 implies that the PGP contract creates value for both parties. This is not surprising as we have a risk-averse supplier and a risk-neutral buyer. The farmer can reduce his risk by selling half of the purchase quantity (i.e., $\alpha^* = 0.5$) at a guaranteed price $g^* == \mu - \frac{\lambda}{2}\sigma^2 q$ at the time of sowing and selling the remaining half at market price P after harvest. Effectively, this means the farmer is buying 'insurance' offered by the buying firm. At the same time, the firm can take advantage of the fact that the risk-averse farmer will accept a guaranteed price g^* that is below the expected market price μ so it can enjoy a lower expected cost in equilibrium besides having a guaranteed supply q. This benefit can be viewed as the buying firm receiving an insurance premium from the farmer. Therefore both 'insured' and 'insurer' are better off.[6]

As a result, at the end of the contract negotiations, the two parties can agree on a PGP contract with the following terms: the quantity y to be purchased equal to the the farmer's intended production q, the buying firm's guaranteed price g, and the proportion α^* of the quantity that would be purchased at the guaranteed price at the time of delivery after harvest (Figure 1).

4.2 Extension 1: When the Buyer Imposes an Upper Limit on α

We now extend our base model to the case when the buyer wants to limit its exposure to price risk. Specifically, the buyer would impose an upper bound $b \leq 1$ so that on $\alpha \leq b$. For example, $b = 0.3$ in the Barilla case. For any given g, the farmer's problem given in (4) can

[6]If the buying firm accounts for the aforementioned commissions charged by the intermediaries, it benefits from an even lower effective cost.

be modified as:

$$\pi_f(g) \;=\; \max_{\alpha\in[0,b]} \;\; [\alpha g + (1-\alpha)\mu - c]\, q - \frac{\lambda}{2}(1-\alpha)^2 q^2\sigma^2. \tag{8}$$

Because the objective fucntion is concave in α, we can use the first order condition to show that the optimal proportion $\alpha^*(g)$ satisfies:

$$\alpha^*(g) \;=\; \min\{1 - \left(\frac{\mu - g}{\lambda\sigma^2}\right)\frac{1}{q},\; b\}. \tag{9}$$

By using the same agrument as in the base case, it is sufficient to focus on the case when $g \in [\mu - \lambda\sigma^2 q,\; \mu - (1-b)\lambda\sigma^2 q]$ to ensure that $\alpha^*(g) \in [0, b]$. Because the range $[\mu - \lambda\sigma^2 q,\; \mu - (1-b)\lambda\sigma^2 q]$ is a subset of the range $[\mu - \lambda\sigma^2 q, \mu]$, Lemma 1 continues to hold so that the participation constraint $\pi_f(g) \geq \pi_f^0$ is satisfied. In this case, we can determine the optimal g^* by solving the buyer's problem (akin to (6)) as:

$$\pi_b \;=\; \min_{g\in[\mu-\lambda\sigma^2 q,\mu-(1-b)\lambda\sigma^2 q]} \;\; [\alpha^*(g)g + \{1-\alpha^*(g)\}\mu]\, q + \mu(r - q) \tag{10}$$

By substituting $\alpha^*(g)$ given in (9) and by considering the first order condition, it is easy to check that the optimal guaranteed price g^* satisfies:

$$g^* \;=\; \min\{\mu - 0.5\lambda\sigma^2 q,\; \mu - (1-b)\lambda\sigma^2 q\}. \tag{11}$$

Substituting g^* into (8), (9) and (10), we obtain the following result:

Corollary 2 *When the buyer imposes an upper limit b on α under the PGP contract, the buying firm will set its guaranteed price $g^* = \min\{\mu - 0.5\lambda\sigma^2 q,\; \mu - (1-b)\lambda\sigma^2 q\}$ and the farmer will select his proportion $\alpha^* = \min\{0.5, b\}$. Also, when $b \geq 0.5$, the farmer's certainty equivalence $\pi_f^* = (\mu - c)q - \frac{3\lambda}{8}\sigma^2 q^2$, the firm's expected cost $\pi_b^* = \mu r - \frac{\lambda}{4}\sigma^2 q^2$, and the results stated in Corollary 1 holds. Also, when $b < 0.5$, $\pi_f^* = (\mu - c)q - \frac{1-b^2}{2}\lambda\sigma^2 q^2$, and the firm's expected cost $\pi_b^* = \mu r - b(1-b)\lambda\sigma^2 q^2$. Furthermore, $\pi_f^* - \pi_f^0 = \frac{b^2}{2}\lambda\sigma^2 q^2 > 0$ and $\pi_b^* - \pi_b^0 = -b(1-b)\lambda\sigma^2 q^2 < 0$.*

Corollary 2 implies that, even when the buyer imposes an upper limit b on α, the PGP contract continues to be mutually beneficial.

4.3 Extension 2: When the Farmer Selects q in Anticipation of the PGP Contract

We now extend our base model to the case when the farmer selects q in anticipation of the PGP contract.[7] This situation can occur when the buyer sends a credible message (or makes a commitment) to the farmer about the PGP contract. With a credible message, the farmer and the buyer engage in a 3-stage game as follows. The farmer first selects q based on the belief that the buyer will offer the PGP contract, then the buyer sets her partially guaranteed price g, and finally, the farmer sets his proportion α. In this subsection, we shall focus on the case when the buyer sends a credible message to the farmer.[8] Also, we shall examine whether it is beneficial for the buyer to send a credible message to the farmer about the PGP contract in advance.

When the farmer believes that the buyer will offer the PGP contract, the farmer can anticipate that the buyer will offer the PGP contract by setting $g^* = \mu - \frac{\lambda}{2}\sigma^2 q$ for any q selected by the farmer, the farmer will select his proportion $\alpha^* = \frac{1}{2}$, and the farmer's certainty equivalence $\pi_f^*(q) = (\mu - c)q - \frac{3\lambda}{8}\sigma^2 q^2$ for any given q as stated in Proposition 1. In the event when the farmer can anticipate the buyer will offer the PGP contract when he decides on q, the farmer can select his production quantity q by solving the following problem:

$$\pi_f^* \quad = \quad \max_{q \leq cap} \ (\mu - c)q - \frac{3\lambda}{8}\sigma^2 q^2, \tag{12}$$

where *cap* is the production capacity as explained in Section 3.1. By considering the first order condition , it is easy to check that the optimal production quantity $q^* = \min\left\{\text{cap}, \frac{4}{3} \cdot \frac{(\mu-c)}{\lambda\sigma^2}\right\}$. Relative to the production quantity for the case when the farmer does not anticipate the PGP contract as given in (1), where $q = \min\left\{\text{cap}, \frac{(\mu-c)}{\lambda\sigma^2}\right\}$, we can conclude that the farmer will produce more if he can anticipate that the buyer will offer the PGP contract.

[7]The authors thank the reviewers for suggesting this extension.

[8]We do not consider the case when the buyer knows the state of the market condition but the farmer knows only about the probability of different states. When there is information asymmetry, the buyer's message can be blurred and the farmer can only update his belief about the state of the market using the Bayes rule. This setting can be modeled as a "cheap talk" game (Crawford and Sobel, 1982), which requires a completely different set up. In addition, the analysis of a cheap talk game is highly complex and there are multiple equilibria. For this reason, the analysis of a cheap talk game is beyond the scope of this paper, and we shall defer this case as future research.

Also, through substitution of q^* into the results as stated in Proposition 1 and direct comparison, we obtain the following result:

Corollary 3 *When the farmer can anticipate the PGP contract when he sets his production quantity, he will set his production quantity* $q^* = \min\left\{cap, \frac{4}{3} \cdot \frac{(\mu-c)}{\lambda\sigma^2}\right\}$*, the buyer will offer the guaranteed price* $g^* = \mu - \frac{\lambda}{2}\sigma^2 q^*$*, and the farmer will select his proportion* $\alpha^* = \frac{1}{2}$*. Also, when* $cap \geq \frac{4}{3} \cdot \frac{(\mu-c)}{\lambda\sigma^2}$*, the farmer's certainty equivalence* $\pi_f^* = \frac{2}{3} \cdot \frac{(\mu-c)^2}{\lambda\sigma^2} > \pi_f^0$ *and the buyer's expected cost* $\pi_b^* = \mu r - \frac{4}{9} \cdot \frac{(\mu-c)^2}{\lambda\sigma^2} < \pi_b^0$*.*

Corollary 3 reveals that, when the farmer can anticipate that the buyer will offer the PGP contract, he will produce more; i.e., $q^* \geq q$. Also, the PGP contract continues to be mutually beneficial, creating a win-win solution for the farmer and the buyer.

Next, we examine whether it is beneficial for the buyer to send a credible message about the PGP contract before the farmer selects his production quantity. For ease of exposition, let us consider the case when cap $\geq \frac{4}{3} \cdot \frac{(\mu-c)}{\lambda\sigma^2}$. In this case, we can apply(1) to show that $q = \frac{(\mu-c)}{\lambda\sigma^2}$. By substituting q into Proposition 1, we can show that, when the farmer cannot anticipate the PGP contract, the farmer's profit is equal to $\frac{5}{8} \cdot \frac{(\mu-c)^2}{\lambda\sigma^2}$ and the buyer's expected cost is equal to $\mu r - \frac{1}{4} \cdot \frac{(\mu-c)^2}{\lambda\sigma^2}$. By comparing these two quantities with those stated in Corollary 3, we can conclude that both the buyer and the farmer can benefit even more from the PGP contract when the buyer can send a credible message about the PGP contract before the farmer selects his production quantity.

5 PGP Contract with Endogenous Purchase Quantity

We now consider the case when the firm's purchase quantity y is a decision variable with $y \leq q$ that is endogenous to the negotiating process. In this case, the firm has to determine its purchase quantity y from the farmer and its guaranteed unit price g. For any given (y, g), the farmer would need to sell his extra units $[q - y]^+$ on the open market accordingly to the ex-ante uncertain market price P. At the same time, the farmer has to decide the proportion α of the purchase quantity y to be paid according to g and the rest according to the realized P.

The farmer sells $y \le q$ units to the firm according to the effective unit price $(\alpha g + (1-\alpha)P)$ and the remaining $(q-y)$ units on the open market at unit price P. Taking into account the unit production cost c, the farmer's *profit* is equal to $[\alpha g + (1-\alpha)P]y + P(q-y) - cq$. Because $P \sim N(\mu, \sigma^2)$, the farmer's certainty equivalence for any given α is:

$$\pi_f(\alpha) = [\alpha g + (1-\alpha)\mu] \cdot y + \mu(q-y) - cq - \frac{\lambda\sigma^2}{2} \cdot (q - \alpha y)^2. \tag{13}$$

Similarly, when the firm purchases y units from the farmer and the remaining $(r-y)$ units from the open market, it is easy to show that the buyer's expected cost satisfies:

$$\pi_b = [\alpha g + (1-\alpha)\mu] \cdot y + \mu \cdot (r-y). \tag{14}$$

We now analyze the Stackelberg game that corresponds to the case when the buying firm chooses its purchase quantity y and offers the guaranteed unit price g – in response, the farmer selects his proportion α. It can be shown that there exists an equilibrium under which the firm will purchase exactly $y^* = q$ units from the farmer and purchase the remaining $(r-q)$ units from the open market. Consequently, we can apply the result from the previous section to show that the PGP contract will continue to create mutual benefits for both parties when the purchase quantity y is not exogenous but rather a decision variable. We state this as:

Proposition 2 *There are multiple equilibria that yield the same payoff for the firm and the farmer when (a) the firm chooses its purchase quantity y and guaranteed unit price g and (b) the farmer is allowed sell his extra $(q-y)$ units on the open market. Among these, there exists one equilibrium under which $y^* = q$ and $g^* = \mu - \frac{\lambda}{2}\sigma^2 q$ as given in equation (7) with the PGP contract increasing utility for both the firm and the farmer.*

Proposition 2 points to an equilibrium in which the firm purchases the entire crop (i.e., $y^* = q$) from the farmer when the firm chooses both purchase quantity $y \le q$ and guaranteed unit price g. Thus, the results presented in Proposition 1 and Corollary 1 continue to hold when the purchase quantity is no longer exogenous and the PGP contract continues to create benefits for both the farmer and the buying firm.

For the remainder of this paper we therefore limit ourself to examining the value of the PGP contract associated only with the exogenous case with $y = q$.

6 PGP Contract with Contractually Required Advisory Services

Now consider adding the required use of advisory services, free to the farmer, as part of the contract. While we expect the farmer's utility to improve further, but we need to better understand how the equilibrium shifts to the advantage of both parties.

Suppose, as a result of the agricultural advisory services, the farmer reduces his unit production cost from c to δc (with $\delta \in (0, 1]$) and increases his yield from 1 to $(1 + \epsilon)$ (with $\epsilon \in [0, 1]$).[9] *For clarity, we scale the purchase quantity q to 1 to focus on the value of the advisory services.*

While the setting is the same as the base case with $q = 1$, a key difference here is that the farmer now can produce $(1 + \epsilon)$ units. If the firm is willing to purchase the extra production ϵ, then we can simply replace $q(= 1)$ by $(1+\epsilon)$, replace c by δc, and then apply Proposition 1 and Corollary 1 to show that the PGP will create mutual benefits. This observation motivates us to consider an alternative scenario in which the firm is not willing to purchase the extra production ϵ. However, the contract allows the farmer to sell his "extra" production ϵ (due to the improved yield) on the open market and obtain additional revenue.

Therefore, for any given guaranteed unit price g (offered by the firm) and proportion α (selected by the farmer), the farmer's profit associated with the case when $q = 1$ is equal to

$$[\alpha g + (1 - \alpha)P] + \epsilon P - \delta c,$$

where the first term in square brackets represents the revenue to be obtained from the firm when $q = 1$, the second term is the additional revenue generated from the extra production ϵ due to yield improvement, and the third term represents the reduced production cost.

Throughout this section, we use the notation $\tilde{x}$ to denote quantity x associated with the case when the firm offers agricultural advisory services in addition to the guaranteed price g under the PGP contract. By using the fact that $E(P) = \mu$ and $Var(P) = \sigma^2$, we can determine the certainty equivalence of the farmer's profit. Therefore, for any given

[9] For ease of exposition, we consider the cases when $\delta \in (0, 1]$ and $\epsilon \in [0, 1]$ that are commonly observed in practice. However, the same approach can be used to analyze the case when $\delta > 1$ and/or $\epsilon > 1$. Also, we assume that δ and ϵ are deterministic for simplicity; however, the analysis can be extended to the case when these two parameters are stochastic.

guaranteed price g, the farmer's problem is:

$$\tilde{\pi}_f(g) \quad = \quad \max_{\alpha\in[0,1]} \ ((\alpha g + (1-\alpha+\epsilon)\mu) - \delta c) - \frac{\lambda}{2}(1-\alpha+\epsilon)^2\sigma^2, \tag{15}$$

where the optimal proportion $\tilde{\alpha}^*(g)$ satisfies:

$$\tilde{\alpha}(g) \quad = \quad 1+\epsilon - \frac{\mu - g}{\lambda\sigma^2} = \epsilon + \alpha^*(g) \tag{16}$$

where $\alpha^*(g)$ is given in (5) with $q = 1$.

Relative to the base PGP case in Section 4, (16) shows that the farmer would take advantage of the PGP contract by shifting the price risk to the firm by increasing his proportion α^* earlier to $\alpha^* + \epsilon$ now when he is allowed to sell his extra production ϵ on the open market. By using the same argument as for the base PGP case, the buying firm can now offer a lower price $g \in [\mu - (1+\epsilon)\lambda\sigma^2, \mu - \epsilon\lambda\sigma^2]$ so that $\tilde{\alpha}(g) \in [0, 1]$.

For exposition, we assume that $\mu \geq 2\lambda\sigma^2$ so that the range $[\mu - (1+\epsilon)\lambda\sigma^2, \mu - \epsilon\lambda\sigma^2]$ associated with g is always non-negative for any $\epsilon \in [0, 1]$. Next, we examine the condition under which the farmer's participation constraint $\tilde{\pi}_f(g) \geq \pi_f^0$ holds, where $\tilde{\pi}_f(g)$ is given in (15) and π_f^0 is given in (2):

Lemma 2 *For any guaranteed price $g \in [\mu-(1+\epsilon)\lambda\sigma^2, \mu-\epsilon\lambda\sigma^2]$, the participation constraint $\tilde{\pi}_f(g) \geq \pi_f^0$ is always satisfied.*

Knowing the farmer will always participate in the PGP contract as per Lemma 2 and the farmer's response $\tilde{\alpha}^*(g)$ is given in (16), the firm determines $\tilde{g}^*$ that minimizes its expected cost (for purchasing $q = 1$ unit from the farmer and the remaining $(r - 1)$ units from the open market) by solving:

$$\tilde{\pi}_b^* \quad = \quad \min_{g\in[\mu-(1+\epsilon)\lambda\sigma^2, \mu-\epsilon\lambda\sigma^2]} \ (\tilde{\alpha}(g)g + (1-\tilde{\alpha}(g))\mu) + \mu(r-1). \tag{17}$$

By substituting $\tilde{\alpha}(g)$ given in (16) and by considering the first order condition, we obtain the optimal guaranteed price:

$$\tilde{g}^* \quad = \quad \mu - (1+\epsilon)\frac{\lambda}{2}\sigma^2. \tag{18}$$

Comparing the guaranteed price g^* for the base case in (7) (for the case when $q = 1$) and $\tilde{g}^*$ for this case in (18), we note that the firm would lower its guaranteed price further when the it offers free advice to the farmer for improving yield. This result is due to the fact that the farmer is allowed to sell his extra production ϵ on the open market, which creates an opportunity for the firm to extract some of the value created by offering a lower guaranteed price $\tilde{g}^*$ as the yield ϵ improves.

By substituting $\tilde{g}^*$ into (16), we can retrieve the optimal proportion that the farmer selects in equilibrium:

$$\tilde{\alpha}^* = \frac{1+\epsilon}{2}. \tag{19}$$

As noted earlier, the farmer would take advantage of the PGP contract by increasing his proportion so that he can shift some of the price risk associated with the sales of his extra production ϵ to the firm. By substituting the optimal $\tilde{g}^*$ and $\tilde{\alpha}^*$ into (15) and (17), we obtain:

Proposition 3 *When the firm offers free advisory service on top of the PGP contract, it will set its guaranteed price $\tilde{g}^*$ as given in (18) and the farmer will select his proportion $\tilde{\alpha}^*$ as given in equation (19) in equilibrium. The farmer's certain equivalence then is*

$$\tilde{\pi}_f^* = (1+\epsilon)\mu - \delta c - \frac{3}{8}\lambda\sigma^2(1+\epsilon)^2 \tag{20}$$

and the firm's expected cost is

$$\tilde{\pi}_b^* = \mu - \frac{\lambda\sigma^2}{4}(1+\epsilon)^2 \tag{21}$$

Note that Proposition 3 reduces to Proposition 1 when $\epsilon = 0$ and $\delta = 1$. Comparing Propositions 1 and 3 for the case when $q = 1$, we obtain:

Corollary 4 *When the firm offers free advisory service on top of the PGP contract, it creates additional mutual benefit in equilibrium: the farmer can increase his certainty equivalence, i.e., $\tilde{\pi}_f^* > \pi_f^*$, and the firm can further reduce its expected cost, i.e., $\tilde{\pi}_b^* < \pi_b^*$.*

Corollary 4 isolates the *additional* benefits created by the (free) advisory services offered by the firm through three operational factors: (1) the farmer can sell the extra production in the open market after harvest; (2) the farmer can shift some of the price risk associated with the extra production to the firm by increasing his proportion; and (3) the firm can take advantage of the extra production by lowering its guaranteed price further relative to the base case.

Considering Corollary 1 and Corollary 4 together, we conclude that (a) the PGP contract creates shared value by sharing price risk as stated in Corollary 1, and (b) free advisory services provide further mutual benefit by balancing the risk associated with the sales of the extra production. Thus, our analysis offers an economic rationale for why such multinational agri-food firms as Barilla, Nestlé, Starbucks and Walmart are not only establishing direct contracts with farmers but also why they are additionally offering free advisory service to these farmers.

7 Guaranteed Price Premium for 'Sustainability' Compliance

Many firms provide incentives for farmers to comply with farming practices that can reduce the harmful effects of agricultural practice on the environment. Such practices include the use of composted plant material or animal manure to enrich soil and the use of ladybugs and spiders to control agricultural pests to decrease the use of chemicals (Gold 2009). We examine the case when a firm such as Barilla (Formentini et al. 2014) or Starbucks (Lee 2007) offers a price premium h to farmers who comply with 'sustainable', 'organic', or meeting the requirements of a third-party certification body or indeed any other desirable farming practices required by the buying firm.

Complying with these requirements is costly for the farmer. Given the contract quantity $q = 1$ and the guaranteed price g, the farmer needs to decide on the proportion α to be paid at g as before. In addition, if the buying firm offers a price premium h proportional to the fraction γ that complies with the practices specified by the firm, the farmer has to decide on this fraction.[10] This form of linear price premium is commonly observed in practice. For example, Lee (2007) reported that, under the C.A.F.E. program, Starbuck's offers \$0.05 per

[10]The same reasoning holds when there are multiple farmers negotiating as a consortium, as in the case of Barilla, and some farmers choose to be fully compliant and others fully non-compliant. In that case, γ would refer to the produce of the compliant farmers.

pound of coffee beans when the farmer complies with the sustainable agricultural practice as specified. As a result of the compliance effort, we suppose he incurs a compliance cost $k\gamma^2$ associated with the proportion γ, which lowers his effective selling price. The expected value of his effective selling price is then $\alpha g + (1-\alpha)\mu + (h\gamma - k\gamma^2)$ and the variance is $(1-\alpha)^2\sigma^2$. The farmer seeks to maximize his certainty equivalence as:

$$\pi_f(g,h) = Max_{\alpha\in[0,1],\gamma\in[0,1]} \ (\alpha g + (1-\alpha)\mu - c - \frac{\lambda}{2}(1-\alpha)^2\sigma^2) + (h\gamma - k\gamma^2).$$

Observe that the farmer's problem is separable in α and γ and the first subproblem,

$$\pi_f(g) = \max_{\alpha\in[0,1]} \ (\alpha g + (1-\alpha)\mu - c - \frac{\lambda}{2}(1-\alpha)^2\sigma^2)$$

is identical to the farmer's problem as presented in Section 3 with $q = 1$. Hence, all results stated in Section 3 continue to hold for the first subproblem: the PGP contract creates shared value for the farmer and the firm.

It suffices therefore to focus on the second subproblem associated with the price premium for compliance. First consider the farmer:

$$\pi_f(h) = \max_{\gamma\in[0,1]} \ (h\gamma - k\gamma^2). \tag{22}$$

The optimal proportion then is:

$$\gamma^*(h) = \frac{h}{2k} \tag{23}$$

Hence, the farmer will choose a larger proportion to comply with the guidelines when the firm offers a higher premium h. Also, by using the same argument presented earlier, it is sufficient to consider the case when $h \in [0, 2k]$ so that $\gamma^*(h) \in [0,1]$. Substituting $\gamma^*(h)$ into the objective function given in (22), we get

$$\pi_f(h) = \frac{h^2}{4k} > 0$$

Thus, price premium creates additional value for the farmer to comply with the guidelines.

The firm anticipates the farmer's response $\gamma^*(h)$ in equation (23) and seeks to determine h^* to minimize its expected *relevant* cost that includes the premium payment $\gamma^*(h)h$ as well as a posited *social cost* $(a - b\gamma^*(h))$ that decreases with the proportion of compliance $\gamma^*(h)$

selected by the farmer. *Social cost is loss of brand value, which in turn is loss of future sales and margin.* Another way to say this would be that the brand value of the buying firm increases with the proportion of compliance $\gamma^*(h)$. Using diverse case studies, Lefevre et al. (2010: p.4) quantify brand value and other social costs avoided (or benefits obtained from such efforts) as a percentage of revenue. Either way, there is potential reduction in margin in the future and for convenience we term it as a cost for the buying firm. Note that brand value is particularly important for agri-food companies that face the consumer by making or selling consumer goods. One category we have not included in the relevant cost is that of *monitoring* by the company to ensure the farmer is not cheating, i.e., claiming compliance without putting in the effort to ensure it – we relegate this to future research (but see Kvaløy 2006).

With its relevant cost in mind, the firm solves the following problem:

$$\pi_b \quad = \quad \min_{h \in [0,2k]} \quad \gamma^*(h)h + \{a - b\gamma^*(h)\}, \tag{24}$$

By substituting $\gamma^*(h)$ given in (23) and by considering the first order condition along with the bound on h, it is easy to check that the optimal premium h^* satisfies:

$$h^* \quad = \quad \min\left\{\frac{b}{2}, 2k\right\}. \tag{25}$$

Substituting h^* into (23), (24) and (22), we obtain:

Proposition 4 *When the firm offer guaranteed premium to entice farmers to comply with certain agricultural practices, the firm will set a price premium* $h^* = \min\{\frac{b}{2}, 2k\}$ *and the farmer will select his proportion* $\gamma^* = \min\{\frac{b}{4k}, 1\}$ *in equilibrium. The farmer's certainty equivalence (associated with this price premium) then is:*

$$\pi_f^* \quad = \begin{cases} \frac{b^2}{16k} & \textit{if } b < 4k \\ k & \textit{if } b \geq 4k. \end{cases}$$

and the firm's expected social cost (associated with the price premium) is:

$$\pi_b^* \quad = \begin{cases} a - \frac{b^2}{8k} & \textit{if } b < 4k \\ a - b + 2k & \textit{if } b \geq 4k. \end{cases}$$

Proposition 4 shows that, with compliance premium, the farmer obtains additional certainty equivalence on top of the certainty equivalence that the farmer obtains through the

PGP contract. Without such a premium, the farmer has no incentive to comply and will set $\gamma = 0$ so that the firm's social cost is equal to a. In this case, Proposition 4 implies that the buying firm can lower its social cost by providing the premium. Thus the compliance premium h^* is mutually beneficial: it entices the farmer to increase his compliance level so that he can increase his certainty equivalence and the firm can reduce its social cost. Hence, we can state:

Corollary 5 *When the firm offers a price premium for compliance on top of a PGP contract, both parties benefit from the PGP contract. Also, the premium bonus creates additional mutual benefit over and above the basic PGP contract: the farmer can further increase his expected certainty equivalence and the firm can further reduce its social cost and therefore its total relevant cost.*

The result stated in Corollary 5 is consistent with the results Barilla has obtained. Specifically, Barilla has managed to reduce its carbon footprint by 30%, reduce farmer's production cost by 30% and increase farmer's production yield by 20%. The company attributes these to the successful implementation of the PGP contract and its incentive for farmers to adopt sustainable agricultural practices. This has led to Barilla getting the European CSR Award in 2013 for its efforts for durum wheat.

8 Conclusion

Motivated by the contracts being offered by Barilla and SABMiller to farmers in lieu of purchasing from the open market, we examined the *partially guaranteed price* or PGP contract. We modeled the interaction of the buying firm and the farmer as a Stackelberg game and showed that the PGP contract creates shared value for the firm and the farmer whether the purchase quantity is given as an exogenous quantity or it is endogenously determined as part of the negotiation process. We also considered additional aspects of such contracts in practice including the use of advisory services and incentives for 'sustainable' agricultural practices. For these we showed that the PGP contract is beneficial to both parties when advisory service is involved and when incentives are provided for sustainable agricultural practices.

While the key insight that both sides of the contract win follows simply from the fact that the buyer is risk-neutral and the supplier is risk-averse, we have shown how the dynamics between the buying firm and the farmer play out in the context of contract farming. Moreover, we have shown that this key insight is robust even with advisory services and incentives.

Thus, our analysis enables us to gain a better understanding about how the PGP contract creates value for both parties. The risk-averse farmer's situation is relatively straightforward: he gains by facing reduced price risk by 'pre-selling' a portion of the purchase quantity at the guaranteed price under the PGP contract and the remaining at the market price – the incentives and the premiums only add to his gain.

The benefit for the buying firm is more involved. Essentially, the risk-neutral firm can reduce its purchase cost by setting its guaranteed price (slightly) below the expected market price so it gains. Recall our earlier comment that this is akin to the firm offering insurance to the farmer, who in turns pays an insurance premium to the buying firm. When the firm offers advisory services, the farmer gains further and because of this extra benefit, the farmer would be willing to accept an even lower guaranteed price than before, which lowers the firm's expected cost. Finally, when the firm offers a price premium to the farmer for sustainable agricultural practices, the firm can reduce its total relevant cost by reducing its social cost (or by improving its brand value) associated with the farmer's compliance.

There are managerial implications: As these contracts create win-win situations for both farmers and buying firms, there needs to be greater use of such contracts at least for agricultural commodities sold by small farmers. As interest grows in sustainability, the use of such contracts becomes all the more important. Large companies buying in bulk volume cannot deal directly with small farmers, hence their attraction to commodity markets. In Barilla's case, the farmers form consortia and Barilla works with multiple such consortia at the same time. Such contracts make sense especially where we have small farmers *and* there is a good way to aggregate farmers as well as their produce. Finally, if a firm is going for PGP contracts, it might as well provide advisory services.

Still, this paper is only an initial attempt to analyze the PGP contract in the context of creating value for both sides. There are extensions one can explore in the near future:

First, we assumed that the farmer's production yield is deterministic. (Although production yield is uncertain in general, this case the output is quite close to expected on account of the control of seeds, fertilizers, and pesticides by Barilla.) Therefore, it is of interest to establish a contract that can create shared value when the farmer faces uncertain market price and uncertain yield, and the firm faces uncertain market price and uncertain demand (Tang et al., 2014). It may be interesting to explore options in this regard (cf. Spinler and Huchzermeier, 2006) and also to look at other types of contracts with a single dominant buyer (cf. Lau et al 2008).

Second, many firms such as RML are disseminating market information to farmers at a subscription price so that they can obtain a more accurate forecast about the future market price (Aker, 2010; Fafchamps and Minten, 2012; Mittal and Mehar, 2012). It would be interesting to establish a subscription pricing contract rather than free advisory services that can create a win-win situation for both the farmer and the company providing the information service.

Third, when dealing with agricultural practices, in this paper we assumed that the farmer is honest in sticking to the terms of the contract and/or the firm can verify the farmer's effort accurately without any cost. However, as mentioned by Babich and Tang (2012) and Plambeck and Taylor (2014), the farmer may cheat by side-selling when the market price is higher than the contracted price and therefore deliver less quantity to the buying firm. With hidden information and hidden actions, it would be useful to develop a mechanism in the contract that would generate mutual benefit. The farmer could also potentially cheat by fraudulently claiming compliance in order to save costs but still claim the incentive. This requires the buying firm to invest in monitoring, resulting in higher total relevant cost. This too needs to be studied as part of future research.

Finally, this paper has focused on the economic benefits to both parties. This work needs to be extended to measures of *social* benefits to the communities in which the farmers live and work. These benefits can in turn be tied to the goodwill of consumers of the products made by the buying company.

All in all, sustainability contracts are vitally important to all players in the agro-food sector: consumers, farmers, farming communities and buying companies! We hope this paper will encourage further research on such contracts in this as well as other sectors.

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Appendix: Proofs

Proof of Lemma 1: By substituting $\alpha^*(g)$ into the objective function given in (4), we get: $\pi_f(g) = (g-c)q + \frac{\lambda\sigma^2}{2} \cdot \left(\frac{\mu-g}{\lambda\sigma^2}\right)^2$. By considering (2), the participation constraint $\pi_f(g) \geq \pi_f^0$ holds when:

$$
\begin{aligned}
gq - cq + \frac{\lambda\sigma^2}{2} \cdot \left(\frac{\mu-g}{\lambda\sigma^2}\right)^2 &\geq \mu q - cq - \lambda\sigma^2 q^2 \\
\frac{\lambda\sigma^2}{2}q^2 - (\mu-g)q + \frac{\lambda\sigma^2}{2} \cdot \left(\frac{\mu-g}{\lambda\sigma^2}\right)^2 &\geq 0 \\
\frac{\lambda\sigma^2}{2} \cdot (q - \left(\frac{\mu-g}{\lambda\sigma^2}\right))^2 &\geq 0.
\end{aligned}
$$

The last equation proves the lemma.

Proof of Proposition 1: By substituting g^* given in (7) into (5), we get $\alpha^* = 0.5$. Then we can show the rest by direct substitution of α^* and g^* into (4) and (6).

Proof of Corollary 1: Recall that the farmer's certainty equivalence $\pi_f^0 = (\mu - \frac{\lambda}{2}\sigma^2 q - c)q$ where there is no contract. Compare this with the farmer's certain equivalence $\pi_f^* = (\mu - \frac{3\lambda}{8}\sigma^2 q - c)q$ under the guaranteed price contract, we can check that the difference is $\frac{\lambda}{8}\sigma^2 q^2$. This proves the first statement. The second statement can be easily obtained in the same manner.

Proof of Corollary 2: The proof follows the same approach as presented in the proof of Proposition 1 and Corollary 1, we omit the details.

Proof of Corollary 3: When cap $\geq \frac{4}{3} \cdot \frac{(\mu-c)}{\lambda\sigma^2}$, the farmer's production quantity $q^* = \frac{4}{3} \cdot \frac{(\mu-c)}{\lambda\sigma^2}$, the buyer's guaranteed price $g^* = \mu - \frac{2}{3}(\mu - c)$, and the farmer will select his proportion $\alpha^* = \frac{1}{2}$. By substituting these quantities into the results as stated in Proposition 1, it can be shown that: $\pi_f^* = \frac{4}{3} \cdot \frac{\mu-c}{2\lambda\sigma^2}$. At the same time, by substituting q given in (1) into (2), it is easy to check that $\pi_f^0 = \frac{\mu-c}{2\lambda\sigma^2}$. Hence, we can conclude that $\pi_f^* = \frac{4}{3}\pi_f^0 > \pi_f^0$. Next, through substitution, it is easy to check that $\pi_b^* = \mu r - \frac{4}{9} \cdot \frac{\mu-c}{\lambda\sigma^2} < \mu r = \pi_b^0$. This completes our proof.

Proof of Proposition 2: For any given (y, g) selected by the firm, let us examine the farmer's best response $\alpha^*(y, g)$. Because $q \geq y$, we can use (13) to show that the farmer's problem can be formulated as:

$$\pi_f = \max_{\alpha} \, [\alpha g + (1-\alpha)\mu] \cdot y + \mu(q - y) - cq - \frac{\lambda\sigma^2}{2} \cdot (q - \alpha y)^2. \tag{26}$$

By considering the first order condition, it is easy to check that $\alpha^* = \min\{\frac{q}{y} - \left(\frac{\mu-g}{\lambda\sigma^2}\right)\frac{1}{y}, 1\}$, which converges to (5) when $y = q$. We have two cases to consider.

Case 1 with $g \geq \mu - (q - y)\lambda\sigma^2$. In this case, it is easy to check that $\alpha^* = 1$. Combine this observation and the fact that $q \geq y$, we can use (14) to show that the buyer solves the following problem $\min_{y \leq q} \min_{g \geq \mu - (q-y)\lambda\sigma^2} gy + \mu(r - y)$. First, for any given $y \leq q$, it is easy to check that the optimal $g^*(y) = \mu - (q - y)\lambda\sigma^2$. Through substitution, it can be shown that the remaining buyer's problem is: $\min_{y \leq q} (\mu r - \lambda\sigma^2(q - y)y)$. Hence, it is easy to show that $y^* = q/2$. Through substitution, we get $g^* = \mu - \frac{\lambda}{2}\sigma^2 q$, $\pi_b^* = \mu r - \lambda\sigma^2(q/2)^2 < \pi_b^0$ and $\pi_f^* = \pi_f^0 + \frac{\lambda\sigma^2}{2} \cdot (q/2)^2 > \pi_f^0$.

Case 2 with $g \leq \mu - (q - y)\lambda\sigma^2$. In this case, it is easy to check from above that $\alpha^* = \frac{q}{y} - \left(\frac{\mu-g}{\lambda\sigma^2}\right)\frac{1}{y}$. Combine this observation and the fact that $q \geq y$, we can use (14) to show that the buyer solves the following problem $\min_{y \leq q} \min_{g \leq \mu - (q-y)\lambda\sigma^2} \{gy - \left(\frac{\mu-g}{\lambda\sigma^2}\right) \cdot g + \mu y - \mu q +$

$\left(\frac{\mu-g}{\lambda\sigma^2}\right)\cdot\mu+\mu(r-y)\}$ and the optimal $g^*=\mu-\frac{\lambda\sigma^2}{2}q$ when $q/2\le y\le q$ and $g^*=\mu-(q-y)\lambda\sigma^2$ when $q/2>y$. So, we need to examine two scenarios:

- **Scenario a:** $q/2\le y\le q$ In this case, $g^*=\mu-\frac{\lambda\sigma^2}{2}q$ and the corresponding $\alpha^*=\frac{q}{2y}$. Through substitution, we get: the firm's expected cost for any given y is equal to $\mu r-\frac{\lambda\sigma^2}{2}\cdot\frac{q^2}{2}$, which is independent of y. Hence, we can conclude that, when $q/2\le y\le q$, there exists an equilibrium that $y^*=q$ so that $\pi_b^*=\mu r-\lambda\sigma^2\cdot(q/2)^2<\pi_b^0$. Similarly, we can show that the farmer's certainty equivalence $\pi_f^*=\pi_f^0+\frac{\lambda\sigma^2}{2}\cdot(q/2)^2>\pi_f^0$.

- **Scenario b:** $q/2\ge y$. In this case, $g^*=\mu-(q-y)\lambda\sigma^2$ and the corresponding $\alpha^*=1$. This corresponds to Case 1 as stated above. Specifically, we get $y^*=q/2$. Through substitution, we get $g^*=\mu-\frac{\lambda}{2}\sigma^2q$, $\pi_b^*=\mu r-\lambda\sigma^2(q/2)^2<\pi_b^0$ and $\pi_f^*=\pi_f^0+\frac{\lambda\sigma^2}{2}\cdot(q/2)^2>\pi_f^0$.

By combining the results, we have shown that there exists an equilibrium such that the buyer purchase $y^*=q$ in equilibrium. This completes the proof.

Proof of Lemma 2: By substituting $\tilde{\alpha}(g)$ into the objective function given in (15), we get: $\tilde{\pi}_f(g)=g+\epsilon g-\delta c+\frac{\lambda\sigma^2}{2}\cdot\left(\frac{\mu-g}{\lambda\sigma^2}\right)^2$. By considering (2), the participation constraint $\tilde{\pi}_f(g)\ge\pi_f^0$ holds if $g+\epsilon g-\delta c+\frac{\lambda\sigma^2}{2}\cdot\left(\frac{\mu-g}{\lambda\sigma^2}\right)^2\ge\mu-c-\lambda\sigma^2$. This condition can be simplified as $[\epsilon g+(1-\delta)c]\cdot\frac{2}{\lambda\sigma^2}+(1-\left(\frac{\mu-g}{\lambda\sigma^2}\right))^2>0$, which holds because $\delta\le 1$. This proves the statement.

Proof of Proposition 3: The expressions are obtained by direct substitution. We omit the details.

Proof of Corollary 3: When cap $\ge\frac{4}{3}\cdot\frac{(\mu-c)}{\lambda\sigma^2}$, the farmer's production quantity $q^*=\frac{4}{3}\cdot\frac{(\mu-c)}{\lambda\sigma^2}$, the buyer's guaranteed price $g^*=\mu-\frac{2}{3}(\mu-c)$, and the farmer will select his proportion $\alpha^*=\frac{1}{2}$. By substituting these quantities into the results as stated in Proposition 1, it can be shown that: $\pi_f^*=\frac{4}{3}\cdot\frac{\mu-c}{2\lambda\sigma^2}$. At the same time, by substituting q given in (1) into (2), it is easy to check that $\pi_f^0=\frac{(\mu-c)^2}{2\lambda\sigma^2}$. Hence, we can conclude that $\pi_f^*=\frac{4}{3}\pi_f^0>\pi_f^0$. Next, through substitution, it is easy to check that $\pi_b^*=\mu r-\frac{4}{9}\cdot\frac{(\mu-c)^2}{\lambda\sigma^2}<\mu r=\pi_b^0$. This completes our proof.

Proof of Proposition 4: The result can be obtained immediately by substituting g^* into (23), (22) and (24). We omit the details.