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A General Equilibrium Theory of Contracts in Community Supported Agriculture

Thomas W. Sproul and Jaclyn D. Kropp*

Abstract

Community Supported Agriculture (CSA) contracts allow consumers to buy claims on a farm’s future production. In turn, the consumer provides working capital to the farm during the growing season. CSA contracts also provide risk management for farmers with limited access to Federal crop insurance by transferring part of the farm’s risk to the consumer. We derive a theory of CSA contract pricing for the two most prevalent types of CSA contracts: yield contracts, in which consumers receive a percentage of the farm’s production, and weight contracts, in which consumers receive fixed quantities. We develop a two-period model in which expected utility maximizing producers and consumers engage in CSA contracting in the first period based on anticipation of yields and spot prices in the second period. Using the model, we generate several testable hypotheses to be explored in future research. Additionally, we present an overview of the data necessary to test the propositions and potential issues data requirements and potential challenges that might arise in related empirical work.

Keywords: agricultural marketing, direct marketing, community supported agriculture, CSA, contract prices, local food, risk premium, risk-sharing

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Running Head: Contracts in Community Supported Agriculture

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Community Supported Agricultural (CSA) programs are a form of direct marketing used by farmers, in which the farmer contracts with consumers prior to harvest to deliver products later in the season. CSA contracting, along with farmers markets, have become a key part of local food and farm-to-table movements. In addition to the benefits received by consumers associated with supporting local farmers, the local farmers also benefit from these contractual arrangements. Since farmers receive the proceeds of CSA contracts before harvest, CSA contracting provides working capital to farmers during the growing season. In addition, consumers purchasing CSA contracts share in the farm’s risks, and thus CSA are an important source of risk management for farmers who may have limited access to Federal crop insurance because the products they produce are not covered, or coverage is limited.

While the concept of CSA programs originated in Japan and Europe in the 1960s, by the 1980s New England farmers began offering CSA programs (Wilkinson 2001). Since the 1980s, CSA programs have spread across the United States; by 2012, over 12,600 farms offered CSA programs (U.S. Departments of Agriculture 2014a). As CSA programs grew in popularity in New England and the rest of the United States, a variety of contract types emerged to meet the needs of both producers and consumers. The key differences between the various contract types hinges on the degree to which consumers share in the farm’s risk.

Although CSA are an increasingly important direct marketing tool used by farms, to our knowledge, a formal pricing model of the different types of contract does not exist in the current literature. Furthermore, to our knowledge, no other studies address the emergence of the various types of CSA contracting. Thus, we develop a two period model of CSA contractual arrangements between consumers and farmers. In the first period, expected utility maximizing farmers and consumer engage in CSA contracting based on expectations of yields and prices in
the spot market in the second time period; then, in the second period, yields are realized and contracts delivers occur. Essentially, the two-period model consists of a general equilibrium in each period with the equilibrium at time 0 informed by expectations of the various states of nature (yield outcomes) at time $T$. Using no-arbitrage principles of futures and options pricing, we derive a theory of CSA contract pricing and develop price relationships between the two most common types of CSA contracts. Since we are primarily interested in the contractual arrangements, we make several simplifying assumptions including that CSA contracting occurs after planting. We then use the derived model to generate some testable propositions to be explored in future research. Namely, (i) yield contracts should have lower market prices than weight contracts, all else equal, (ii) whether farmers specialize in one contract type, or sell a mix of both, will depend on the covariance of prices and revenues which affects the value of each contract type as a hedge against income risk, and (iii) crop diversification will reduce CSA contract offerings by farmers specialized in one contract type, but may not reduce offerings by farmers selling a mix of contract types. We conclude by discussing the data needed to test these propositions as well as potential issues one might encounter when undertaking empirical work.

**CSA Contractual Terms and Types of CSA Contracts**

Most farms’ CSA contracts provide the consumer, often referred to as a “member” or “shareholder”, with a basket of products to be received at regular intervals throughout the contract period. While some farms might include all products produced on the farm in its CSA contract, other farms specify only a few crops or a single crop to be included. Thus, the products offered vary widely across contracts. CSA contracts are typically written for a season, which is usually 8-14 or 20-26 weeks. During the season, the CSA members typically receive their portion of the contracting farm’s harvest on a weekly or bi-weekly basis. While the majority of
farms offering CSA contracts require members to pick up their portion of the harvest at the farm or a farmers market, some CSA farms deliver the products directly to their members’ homes or places of business. Although CSA contracts provide the promised products to the consumers over the course of several weeks or months, for tractability we assume that CSA contracting occurs at time 0 and that all products are delivered simultaneously at time $T$. This allows us to focus on the types of CSA contracts offered by farms and the pricing relationships between the contract types.

The majority of CSA contracts’ terms are structures such that members receive a specified percentage of the various products produced by the farm throughout the season. Because the members engaging in this type of arrangement receive a specific proportion of the farm’s output (total yield), the exact amount (weight) of each product to be received is not specified in advance in the contract, as the amount depends on the farm’s actual production of the product(s) under contract. In effect, the value of what the member receives at time $T$ is equal to a percentage of the farm revenue. In other words, the member shares in the contracting farm’s revenue risk or combined production (yield) and price risks. We refer to these contracts as “yield contracts.”

Other CSA contracts are structured such that they provide consumers with a predetermined, fixed quantity or weight of each covered product at harvest. We refer to these contracts as “weight contracts.” These types of CSA contracts are similar to forward contracts in that the farm has committed to selling a pre-specified quantity at a fixed price. In this case, the price risk is removed for both consumer and producer, but the farm bears the full burden of the yield risk without the benefit of price risk as a natural hedge. Price risk acts as a natural hedge
for yield risk in the production of agricultural products because prices and yields are usually negatively correlated, due to spatial correlations of weather and supply-and-demand effects.

Still other CSA contracts are structured such that they operate as a debit system; members pre-pay by purchasing a CSA contract at the beginning of the season and receive a fixed dollar amount to spend at the farm over the season. Typically, these members receive an explicit discount (usually 10%) off the prevailing prices of these commodities when they make their purchases using their debit balance. We refer to these contracts as “debit contracts.” In this case, the members may not share directly in the farm’s risks, but still provide working capital to the farm. Lastly, some CSA farms offer “you-pick”, where members are given some choice in the products they receive. With “you-pick” contracts, at each pickup, members make selections among similarly-valued options. Thus, “you-pick” contracts resemble debit shares because choices are arranged according to market value.

Benefits to Consumers and Producers from CSA Contracting

While there is a dearth of studies investigating the risk-sharing nature of contractual arrangements of CSA programs, several studies investigate the factors that determine consumer participation in CSA programs, consumer benefits associated with CSA program participation, the effects of CSA program participation on local communities, and the effects of CSA contracting on farms (see Brown 2002 and Brown and Miller 2008 for a review of this literature). We present an overview of previous studies pertaining to CSA programs. However, in general, these studies are descriptive in nature, anecdotal, or take a case study approach with information drawn from a small sample of farms. The lack of more comprehensive studies is likely driven by challenges encountered in obtaining data pertaining to CSA contracting and participation. We will discuss some of these challenges in later sections.
Kolodinska and Pelchb (1997) use a sample of 286 survey respondents to draw conclusions about the determinants of CSA program participation by consumers. Using data collected through phone interviews of non-members, members and former members of three Vermont CSA farms and a binomial logit model, they found that households with children under 12 or with teenagers were less likely to join a CSA program, while more educated households and households who regularly buy organic products were more likely to join. They also found a negative relationship between price of the CSA contract and the likelihood of membership. However, there was no significant relationship between household income and the probability of joining a CSA program.

Consumer benefits associated with CSA membership include access to locally grown, fresh products throughout the growing season, improved nutrition and cost savings as well as social benefits. A study of four CSA programs in Pennsylvania found that members increased both the quantity and variety of produce that they consumed as a result of joining their CSA (Oberholtzer 2004). Similarly, Ostrom (2007) found CSA members in Minnesota and Wisconsin reported increased consumption of vegetables, consumption of a greater variety of vegetables, and changing to healthier eating habits as a result of CSA membership. Several studies suggest that CSA members spend less on CSA memberships than they would spend if they purchased the same bundle of goods at the grocery store (Cooley and Lass 1998; Farnsworth et al. 1996; Sabih and Baker 2000). Furthermore, Farnsworth et al. (1996) concluded CSA members’ decisions to join CSA programs were dominated by the social or “club” benefits they provide. These benefits included sharing and supporting common interests, value added from having someone else select their vegetables, altering their eating habits, and giving their excess produce to neighbors and friends. Consumers might join a CSA due to preferences for supporting local producers. Darby
et al. (2008) found consumers are willing to pay almost double for products produced “locally” relative to products from more distant locations, holding freshness constant.

Connolly and Klaiber (2014) analyzed consumer valuations of CSA contract attributes by developing a hedonic model based on firm-level prices. Using data from 453 CSA farms in Michigan, New York, Ohio, and Pennsylvania, they estimated consumer valuations of CSA contract attributes, including product offerings, CSA contract length, number of pick up days per week, and production techniques such as various types of organic certification, pest management and naturally grown certification. They found an 8% premium for CSA contracts offering fresh-cut flowers in addition to fresh vegetables, suggesting that CSA contracts covering a more diverse bundle command higher prices. However, the effect of adding fruits or animal products (dairy products, meat or eggs) to the contract was not statistically significant. They also found that consumers had a positive and economically significant valuation of certified organic produce provided by local CSA farms (7% premium). Consumers had positive valuations of other attributes as well, which suggests that CSA farms can obtain a price premium by differentiating themselves through marketing. However, the authors did not control for contract type in their model; perhaps, because variation in contract type was not present in their sample. Our model presented in the next section shows how contract type influences the CSA share price, and hence how ignoring contractual arrangements can lead to biases associated with missing variables if the contractual terms are not controlled for when engaging in empirical analysis.

CSA programs also provide benefits to farmers such as financial security and the provision of working capital during the growing season. CSA contracting enables producers to receive better prices for their crops, gain financial security as revenues are received before harvest, and reduce the burden of marketing their commodities (U.S. Department of Agriculture
Sabih and Baker (2000) found, using a case study approach, that a Canadian farm offering CSA contracts was better off financially (had a higher return) than it would have been had it sold its vegetables to the wholesale market and financed its operations through conventional means such as line-of-credit or loan financing. Welsh (1997) suggested that the rise of CSA contracting as well as farmer markets was partially driven by changes in the structure of agriculture in which producers farm-level production decisions are increasingly being driven by off-farm firms such as processors; so, CSA contracting allows the farm to maintain control over production decisions.

While few studies attempt to model CSA contract prices, prior literature states that the price of a CSA contract is typically set such that the operating costs, including a fair return to the farmer's labor, can be covered (Brown and Miller 2008; Fieldhouse 1996). However, several studies found that producers are not satisfied with their CSA program’s ability to cover their costs. Only 46% of respondents to the 2001 national CSA survey indicated they were satisfied with their ability to cover operating costs (Lass et al. 2003). Using survey data from farmers in nine Midwestern states, Tegtmeier and Duffy (2005) found farms offering CSA programs considered operational costs but not their labor costs when setting their CSA contract prices. In a working paper, Lizio and Lass (2005), use four years of survey data from CSA farms in the Northeast United States to show that CSA farms cover their costs only if farm operator’s labor is not included. They also found CSA farms to be primarily price takers, consistent with Connolly and Klaiber’s (2014) and Lizio and Lass (2005) findings that CSA farms exhibit little market power. This suggests that CSA share prices are not determined solely by production costs.

This current paper fills the gap in the existing literature by developing a pricing model of the various types of CSA share contracts. Our pricing model is derived from futures and options...
pricing, and it predicts that contracts in which consumers do not share in production risk, such as “weight contracts”, will be priced higher than contracts in which the consumer shares in both price and yield risk (“yield contracts”), all else equal. The higher price for weight contracts includes a risk premium. We also model the decisions of farmers about which contract types to offer while hedging risks. To our knowledge, the pricing of these different types of CSA contracts and farmers’ contract supply decisions have not been formally modeled.

**A General Equilibrium Model of CSA Contracting**

Farmers may offer CSA contracts for sale depending on prevailing market contract prices, knowledge about planting decisions and production technology, and expectations of future crop prices at harvest. Consumers (including all non-farm producers) can choose to enter into CSA contracts depending on prevailing contract prices and expectations about future spot prices of the products under contract, according to their consumption and risk preferences. We assume all contracts are delivered at harvest time; specifically, we assume that farmers engaging in weight contracts cannot renge on the contracts and thus deliver all promised commodities even if this requires the farmers to purchase shortfalls in the spot market. After consumers receive the proceeds of their CSA contracts, spot markets clear for crops, with prices determined according to crop yields, availability of other goods and the preferences of all market participants. Hereafter we refer to all products under CSA contracts as “crops” or “produce”, but our use of these terms does not preclude the farmer from producing dairy products, eggs or livestock products, etc.

All expectations governing market clearing for CSA contracts are solved by backwards induction. Specifically, the spot market prices for products at harvest time are determined in general equilibrium. The equilibrium prices in the spot market are a deterministic function given
the endowments and preferences of market participants, so price expectations are calculated from equilibrium prices across all states of nature. Here, states of nature are all possible combinations of yield outcomes across crops and their associated probabilities.

We assume that planting decisions are made prior to CSA contracting decisions. In reality, planting and CSA contracting may occur simultaneously or overlap in time, but we simplify them into discrete stages for analytical tractability. Having contracts bought and sold after planting but before harvest preserves a realistic modeling component: farmers have proceeds of contract sales as working capital in the event of credit constraints. In reality, farmers make their planting decisions to maximize expected utility over the joint distribution of CSA contract prices and yields, which crops are viable to grow, production costs and technology, and land constraints. We ignore planting decisions in our model so that we can focus on the risk-sharing aspects of CSA contractual arrangements.

The CSA contracting market is a financial general equilibrium with contracting over states of nature, as opposed to the post-harvest goods general equilibrium. There are no initial endowments of contracts, so buyers and sellers are determined in equilibrium according to their respective expected utilities and their other endowments (e.g., productive agricultural land, etc.). These expected utilities are based on expectations about the spot market’s state post-harvest. Essentially, utilities post-harvest are defined over tradable spot produce but not over tradable contracts, whereas expected utilities during the contract market are defined over tradable contracts and expectations about spot produce prices. Farmers’ expected utilities in the contract market are also informed by knowledge of their production technology and costs, land capacity, and any constraints they face.
Thus, though price and utility expectations are solved via backwards induction, we envision a simple process. At time $t = 0$, farmers and consumers transact on CSA contracts and equilibrium contract prices are determined as the contract market clears. At time $t = T$, the crop is harvested, contract deliveries are realized and equilibrium crop spot prices are determined as that market clears. We present the model stages in reverse order because all expectations in the earlier period are functions of optimal decision-making in the latter period.

*Post-Harvest General Equilibrium ($t = T$)*

After crops are harvested, prices are determined in general equilibrium. Consumer endowments of produce are zero unless they purchased a CSA contract in the earlier period. If any consumer bought a CSA contract, his endowments for each of the included crops is increased by the contract deliveries, while the selling farmer’s endowments are reduced by the same amount. Every farmer’s endowment of each crop is the realized crop yield less contract deliveries to her customers. A farmer having a negative endowment for any one crop means she did not produce enough to cover her contractual commitments. In this scenario, the farmer will have to make up the shortfall by purchasing the crop in the spot market.

Farmers and consumers are assumed to have a strictly increasing and strictly concave, von-Neumann and Morgenstern (vNM) utility function, $u(x)$, over the vector of all consumption goods, $x$. While we do not assume a particular functional form for $u(x)$, we do assume utility is bounded above and $u(0) = -\infty$. For simplicity, consumers and farmers only consider utility of post-harvest consumption ($t = T$), ignoring intermediate consumption during the first stage of the model. Consumption utility in the final period includes all consumption goods, $x$, of which food crops are a subset, so the post-harvest general equilibrium is in fact a model of the full market for local food, other food, and all other goods.
We assume there are \( I \) consumers, each with endowment vector \( w_i \) and a consumption vector \( x_i \). There are \( J \) farmers, each with endowment vector, \( w_j \), and consumption vector, \( x_j \).

Given prices, each consumer solves the Lagrangian:

\[
\max_{x_i} \mathcal{L} = U(x_i) + \lambda_i p \cdot (w_i - x_i)
\]

where \( p \) is the vector of prices, \( \lambda_i \) is the Lagrange multiplier for consumer \( i \) at time \( t = T \), and \( p \cdot (w_i - x_i) \) is the budget constraint which sets the value of the endowment equal to the value of consumption, given prices. The farmer problem is identical with subscripts \( j \). There are \( M \) consumption goods denoted \( x_m \), so a consumer’s (or farmer’s) consumption of good \( m \) is denoted \( x_{im} \) (or \( x_{jm} \)). Farmers’ yields for each crop are denoted \( y_{jm} \), and we use yields to mean total production of the crop by that farmer, not production per acre or other unit of land. Farmer \( j \)’s total contract amounts sold for each crop are \( c_{jm} \leq 0 \), so her endowments for crops she produces are \( w_{jm} = y_{jm} + c_{jm} \). Conversely, consumers’ endowments of food crops are \( c_{im} \).

The necessary first order condition of the Lagrangian for each good \( m \) is:

\[
\frac{\partial U(x_i^*)}{\partial x_{im}} - \lambda_i^* p_m = 0
\]

where \( U' > 0 \) by our assumptions and \( \lambda_i^* \) is the shadow price of the budget constraint, which is given in this case by price times endowments. The first order conditions give an implicit solution for the consumer’s demand, and strictly concave utility ensures a unique demand vector, \( x_i^*(p) \), as a function of any vector of positive prices, \( p \in \mathbb{R}_{++}^m \). Similarly, farmers’ demands are denoted \( x_j^*(p) \), but they may differ from consumers’ demands due to larger endowments of certain food crops (and resulting budget constraints), and, possibly, different preferences.
General equilibrium prices are then determined by the unique price vector, $p^*$, that sets aggregate excess demand of all consumers and farmers to zero for all $M$ goods. $p^*$ solves
\[ \sum_i (x_i^* - w_i) + \sum_j (x_j^* - w_j) = 0. \] Strictly concave, increasing utility functions for all market participants guarantee existence of a unique equilibrium price vector, $p^*$, satisfying the above. Equilibrium demands are then, e.g., $x_i^*(p^*)$, satisfying the budget constraint, $p^* \cdot x_i^* - p^* \cdot w_i = 0$. The equilibrium prices serve to allocate goods across the economy in a manner that matches endowments to demands. Thus, equilibrium prices, $p^*$, necessarily depend on farm yields.

**Contract Market Equilibrium ($t = 0$)**

In the first time period, farmers and consumers are able to enter into contracts with respect to the various CSA crops, but may choose not to do so. We model this set of choices in what follows. First, we establish the general equilibrium in the contract market, and then we evaluate specific contract types such as yield shares and weight shares. We assume that in the contract market farmers and consumers can contract on any one crop (with infinitely divisible quantity). Farmers may contract with many consumers or even with each other, and the same applies to consumers.

To make this precise, we define states of nature in terms of outcomes of the endowments matrix, $w(\omega) = (w_1(\omega), ..., w_{I+J}(\omega))^T$, which incorporates both the set of yield outcomes and the possibly random endowments of non-crop goods. The aggregate endowments matrix, $s_{\Omega \times (I+J) \times M}$, contains endowments matrices, $s_\omega = w(\omega)$, specifying the endowments of all agents in each state, $\omega$, at time $t = T$. Probabilities of endowments matrices are defined by the probability space, $(\Omega, \mathcal{F}, \mathcal{P})$, where $\Omega$ is the set of all outcomes, $\mathcal{F}$ is the set of all subsets, and $\mathcal{P}$ is a probability measure.
Arrow (1964) showed that such a general equilibrium exists with uncertain future endowments of many goods, so long as agents are risk averse and are price-takers. In particular, if spot markets with anticipated prices exist for all consumption goods, then all consumption decisions are spanned by trading on the numeraire using Arrow securities. The state prices of these securities are positive and will sum to one if there is no arbitrage. Thus, the state prices can be interpreted as a risk-adjusted probability distribution, $Q$. Also, trading does not have to be in terms of Arrow securities if markets are complete; all prices of more complex instruments are simply recovered from their fair prices (expected value) under $Q$.

We first start with some observations. Usually: (i) consumers will have zero endowments for crop goods ($s_{imo} = 0$) so they will be net buyers, (ii) farmers will have zero endowments for crop goods they do not produce ($s_{jmo} = 0$) so they will be net buyers for these goods, and (iii) farmers will have large positive endowments for crop goods they do produce ($s_{jmo} > 0$), so they will be net sellers for these goods.

**Pricing of CSA Contract Types**

We can now define the contract types of interest in a more intuitive manner than afforded by the Arrow securities. In a yield contract, $c^y_{mij}$, farmer $j$ commits a fixed percentage, $\alpha$, of her random yield to consumer $i$, so $c^y_{mij} = \alpha_i y_{mj}$. In a weight contract, farmer $j$ commits a fixed quantity, $c^w_{mij}$, to consumer $i$. Consumer $i$’s net contracts on crop $m$ across all farmers are $c_{mi} = \sum_j \left(c^y_{mij} + c^w_{mij}\right)$, where it is possible that many (or all) farmers do not contract with consumer $i$ and usually $c_{mi} \geq 0$. Similarly, farmer $j$’s net contracts on crop $m$ are $c_{mj} = -\sum_i \left(c^y_{mij} + c^w_{mij}\right)$,
and usually $c_{mj} \leq 0$. Contracts can only exist if they have both buyers and sellers, so for any crop $m$, we must have that $\Sigma_i c_{mi} + \Sigma_j c_{mj} = 0$.

Finally, contracts do not exist without some form of payment. In the contract market, the buyer pays the seller from their endowment of the numeraire good ($m = 1$). Each contract’s unit price is recovered from the risk-adjusted distribution, $Q$, and is denoted $q^w_m$ for weight and $q^y_{mj}$ for yield. We allow the yield unit price to be unique for each seller due to differing distributions of their random yields, which could be due to production technology, land quality, etc. The weight unit price does not vary because we assume away quality considerations; general equilibrium with no arbitrage requires the weight unit price to be the same across sellers since there is no risk in delivery. Accordingly, if consumer $i$ buys contracts from farmer $j$, the net payment of numeraire will be $q^w_m c^w_{mi} + q^y_{mj} c^y_{mj}$, with either term being set to zero if that contract type is not purchased.

To make comparisons between contract types, we evaluate them according to their payoffs in each state. Intuitively, this is because consumers may adjust their demands even after receiving contract deliveries or otherwise expect to participate in the spot market. In particular, consumers may expect to buy some percentage of their consumption in the spot market, and may even end up as sellers in the spot market if plans change or if they receive too much quantity from a yield contract.

The value of the yield contract at harvest is equal to a percentage of the farm’s yield times the crop’s spot price at harvest, $p^*_m$, denoted $v\left(c^y_{jm}\right) = \alpha_j y_{jm} \cdot p^*_m$ which is equivalent to a percentage share, $\alpha_j$, of the farmer’s realized revenue for crop $m$. Under our assumptions for
general equilibrium, the equilibrium contract price must equal its expectation under the risk-adjusted probability distribution, \( Q \): 

\[
q^v_{jm} = \mathbb{E}_Q \left[ \nu \left( c^v_{jm} \right) \right].
\]

Weight contracts, on the other hand, deliver a fixed quantity, \( c^w_{jm} \), at a pre-arranged price, \( q^w_m \), in the manner of a similar to forwards contract, so their value at harvest is 

\[
\nu \left( c^w_{jm} \right) = c^w_{jm} \left( p^*_m - q^w_m \right).
\]

By no arbitrage, it must be that the weight contract is also priced according to the risk-adjusted distribution, so: 

\[
q^w_m = \mathbb{E}_Q \left[ p^*_m \right].
\]

It is not guaranteed that the two contract types offer the same quantities in expectation. For example, consider the basic model of farm production under risk by Lapan and Moschini (1994), with optimal hedging in futures markets depending on the farmer’s risk aversion, the yield-price covariance, and the basis risk. Even if farmers are identical except with respect to contract type, the model is likely to imply different optimal hedges when futures or forward markets (or weight shares) are used for hedging than when general shares are used to hedge. To account for this, let \( \Delta c_{jm} = c^w_{jm} - \mathbb{E}_Q \left[ c^v_{jm} \right] \) denote the difference between the weight contract quantity and the expected yield contract quantity (with expectation priced by the market).

In the case of weight contracts, the seller is responsible to make up any quantity shortfalls on the open market, and therefore may bear more risk than under a yield contract arrangement. While the forward contract structure of the weight contract removes price risk, it also removes the natural hedge of prices against yields due to their negative correlation, which is induced by spatial weather correlations and supply-and-demand factors. Proposition 1 formalizes the price relationship between yield and weight contract prices for a given farmer.

**Proposition 1.** Given complete markets with no arbitrage, the price relationship between yield and weight contracts is given by:
Proofs of all propositions can be found in the supplementary appendix online. Proposition 1 makes explicit the risk pricing differences of the two contract types in the general equilibrium market for contracts. For any farmer, \( j \), the price premium of a weight contract has two components, a yield premium, \( q^w_j c^w_j \), and a risk premium, \(-\text{Cov}_{Q}(y_j, p^*_m)\). The yield premium accounts for potential systematic differences in the expected yields between the two contract types, while the risk premium compensates the farm for the removal of price as a natural hedge on yield risk. Thus, if \( \text{Cov}_{Q}(y_j, p^*_m) < 0 \) (post-harvest spot prices are negatively correlated with yields), then weight contracts will be more expensive unless they are expected to deliver a substantially smaller quantity than yield contracts. If the (risk-adjusted) expected yield from the yield contract is equal to the guaranteed quantity of the weight contract \( (\Delta c^w_j = 0) \), then the yield premium is zero and the price premium of weight contracts (relative to yield contracts from the same farmers) will equal the covariance of yield and harvest price.

**Optimal Contracting Decisions for Risk Management**

It is important to recognize that contract market equilibrium prices tell only part of the story – farmers’ choices to offer weight or yield contracts and in what quantities depend on their risk preferences, in addition to the risk management features of each contract and on prevailing market prices. Consider, for example, a farmer growing a single crop, \( m \), and assume that her general equilibrium utility over future consumption is collapsed to a concave utility over her future budget set. She maximizes expected utility over parameters, \( b^w \) and \( b^y \), representing allocations to weight contracts and to yield contracts respectively, where \( b^y \) is in units of percentage of the yield. Her objective is then:
We can use the familiar mean-variance Taylor approximation of expected utility to approximate expected utility as a function of the mean and variance of income.

$$E(U(X)) \approx U(\mu) + \frac{1}{2} \sigma^2 \frac{U''(\mu)}{U'(\mu)} = U(\mu) - \frac{1}{2} \sigma^2 R_a(\mu),$$

where $R_a$ is the coefficient of absolute risk aversion, evaluated at the mean of $X$, and where:

$$\mu = b^y q_{ym} + b^w q_{wm} + (1 - b^y) E[y_m \hat{p}_m] - b^w E[p_m^*];$$

and

$$\sigma^2 = (1 - b^y)^2 \text{Var}[y_m \hat{p}_m] + (b^w)^2 \text{Var}[p_m^*] - (1 - b^y) b^w \text{Cov}[y_m \hat{p}_m, p_m^*].$$

The necessary first order condition for the farmer’s problem for each $b \in \{b^w, b^y\}$ is:

$$\frac{\partial EU}{\partial b} \approx U', \frac{\partial \mu}{\partial b} - \frac{1}{2} R_a \frac{\partial \sigma^2}{\partial b} = 0,$$

where we assume away indirect effects on the absolute risk aversion coefficient (via small changes in the mean) as second-order small. Thus, this is the classic mean-variance utility model in which expected utility is increasing in mean income and decreasing in the variance of income. Each contracting choice maximizes utility by sacrificing mean income to reduce variance. It can also be verified without the Taylor approximation that this choice problem is concave and the optimal choice is unique.

The marginal effect of each contracting choice on mean income is a loss of the market equilibrium risk premium. The risk premium equals expected contract value minus market price, which is reasonably assumed to be positive (and guaranteed so by our general equilibrium model):

$$\frac{\partial \mu}{\partial b^y} = q_{ym} - E[y_m \hat{p}_m^*] < 0,$$
\[ \frac{\partial \mu}{\partial b^w} = q^w_m - E[p^*_m] < 0. \]

The marginal effect of each contracting choice on the variance of income is a function of the choice for the other contract type, the covariance of revenues and prices, and either the variance of revenue or the variance of price. The marginal effects on variance of income are:

(11) \[ \frac{\partial \sigma^2}{\partial b_y} = -2(1 - b^y) \text{Var} \left[ y_m p^*_m \right] + b^y \text{Cov} \left[ y_m p^*_m, p^*_m \right], \]

and

(12) \[ \frac{\partial \sigma^2}{\partial b_w} = 2b^w \text{Var} \left[ p^*_m \right] - (1 - b^w) \text{Cov} \left[ y_m p^*_m, p^*_m \right]. \]

A key feature of these relationships is that the value of weight contracts as a hedge depends on the covariance of revenues (price times yield) and prices. The cross partial effect on mean income is zero \( \left( \frac{\partial^2 \mu}{\partial b^y \partial b^w} = 0 \right) \), but the cross partial effect on variance of income is exactly equal to the revenue-price covariance:

(13) \[ \frac{\partial \sigma^2}{\partial b^y \partial b^w} = \text{Cov} \left[ y_m p^*_m, p^*_m \right]. \]

Despite our assumption of negative yield-price covariance \( \left( \text{Cov} \left[ y_m, p^*_m \right] < 0 \right) \), the sign of the revenue-price covariance is not known with certainty. The sign of \( \text{Cov} \left[ y_m p^*_m, p^*_m \right] \) may be positive or negative depending on the nature of the statistical dependence structure between prices and yields, even when \( \text{Cov} \left[ y_m, p^*_m \right] \) is assumed to be negative.

**Proposition 2.** Assuming risk-averse farmers and system parameters such that contract sales are non-negative \( \left( b^{w*} \geq 0, b^{y*} \geq 0 \right) \), then:

**Claim 2.1.** Positive price-revenue covariance implies farmers may specialize or diversify contract offerings. Formally, \( \text{Cov} \left[ y_m p^*_m, p^*_m \right] > 0 \implies b^{y*} \in [0,1), b^{w*} \geq 0. \)
Claim 2.2. Negative price-revenue covariance and positive sales of weight contracts can only co-exist if farmers simultaneously oversell yield contracts (above 100%). Formally,

\[ b^{w*} > 0 \cap \text{Cov}[y^*_m p^*_m, p^*_m] < 0 \Rightarrow b^{w*} > 1. \]

Claim 2.3. Except as in Claim 2.2, non-positive price-revenue covariance implies zero sales of weight contracts and partial or zero sales of yield contracts. Formally,

\[ \text{Cov}[y^*_m p^*_m, p^*_m] \leq 0 \cap b^{w*} < 1 \Rightarrow b^{w*} = 0. \]

Claim 2.4. Positive price-revenue covariance implies optimal choices for \( b^{w*} \) and \( b^{y*} \) will diverge in response to changes in the price-revenue covariance. Formally,

\[ \frac{\partial b^{w*}}{\partial \text{Cov}[y^*_m p^*_m, p^*_m]} > 0 \quad \text{and} \quad \frac{\partial b^{y*}}{\partial \text{Cov}[y^*_m p^*_m, p^*_m]} \leq 0. \] Marginal effects of price changes are ambiguous without further assumptions.

Proposition 2 shows how farmers will make tradeoffs between yield contracts and weight contracts according to parameters they face, focusing on the sign of the price-revenue covariance. Other than the edge case of extreme negative covariance supporting weight contracts alongside oversold yield contracts (Claim 2.2), non-positive covariance of prices and revenues translates to zero sales of weight contracts and farmers offering yield contracts only, if at all. On the other hand, positive covariance of prices and revenues is the only regime supporting diversification across contract types, so farmers may offer either or both contracts in positive quantities while not overselling the yield contracts. Here, if positive quantities of both contract types are sold, the contract mix will be sensitive to the covariance; yield contracts will optimally decrease as positive covariance increases further, while weight contracts will optimally increase, all else equal (including prices). Intuitively, the yield contract offers a perfect hedge against risk while the weight contract offers an imperfect hedge. Increasing the price-revenue covariance (prices constant) improves the hedging value of weight contracts relative to yield contracts.
Effects of Crop Diversification on Optimal Contracting

The first order conditions also tell us about the benefits of diversification as a risk management tool for farmers. When farmers are specialized in the production of a specific product, crop diversification may come at a low cost while substantially reducing variance. The risk management benefits of diversification will be strongest when the covariance of prices and revenues across crops is low.

To show the effects of diversification, we present an example derived from the mono-crop farmer of the previous section. Suppose this farmer is able to split her farm equally between two crops with independent and identically distributed (IID) yields, prices and revenues, as well as identical market prices for both contract types. The symmetry of our example problem means contract choices will be identical for each crop \( b_1^y = b_2^y = b^y / 2, b_1^w = b_2^w = b^w / 2 \), so we can make meaningful comparisons of total contracting of the diversified farmer versus the mono-crop farmer. Since both halves of the farm are now IID for the diversified farmer, all variance and covariance terms within crops and prices are halved \( \text{e.g., } 2 \text{Var}[0.5 X] = 0.5 \text{Var}[X] \). The net effect of this change is to cut in half the marginal effect of contract choices on the variance of income. In particular, Equations 11 and 12 are multiplied by one-half to become:

\[
\frac{\partial \sigma^2}{\partial b^y} = -(1 - b^y) \text{Var}[y p^*] + \frac{1}{2} b^w \text{Cov}[y p^*, p^*], \quad \text{and}
\]

\[
\frac{\partial \sigma^2}{\partial b^w} = b^w \text{Var}[p^*] - \frac{1}{2} (1 - b^y) \text{Cov}[y p^*, p^*],
\]

where we remove crop subscripts \( (m) \) due to identical crop distributions for both crop 1 and crop 2. Since marginal mean income effects are unchanged, the diversified farmer will modify contracting choices to double the marginal effects on variance (relative to the mono-crop...
farmer’s choices), if possible. If the new parameters are such that an interior solution cannot be maintained, then corner solutions of zero sales will occur for one or both contract types.

**Proposition 3.** Assuming diversification means division of the farm into IID crops as described above, we compare the choices of diversified farmers against those of mono-crop farmers, all else held equal:

**Claim 3.1.** Diversification will cause some farmers to move from an interior solution (positive sales) in both contracts to a corner solution (zero sales) in at least one.

**Claim 3.2.** Effects of diversification on farmers who maintain an interior solution cannot be signed without further assumptions; this includes the extreme case of speculation under large negative covariance.

**Claim 3.3.** Diversification will cause farmers with \( b^{\text{yw}} = 0 \) to double the amount held back from yield contracts, \((1 - b^{\text{yw}})\), or else move from \( b^{\text{yw}} \leq 0.5 \) to \( b^{\text{yw}} = 0 \). That is, these farmers will have \( b^{\text{yw}} \) unambiguously decrease.

**Claim 3.4.** Diversification will cause farmers with \( b^{\text{yw}} = 0 \) to decrease the amount of weight contracts, \( b^{\text{ww}} \), to a new interior solution, or else move to \( b^{\text{ww}} = 0 \) from

\[
b^{\text{ww}} \leq 0.25 \cdot \text{Cov} \left[ y^{\text{p}} \right] / \text{Var} \left[ p^{\text{y}} \right].
\]

Proposition 3 shows that diversification will reduce the scale of contracts sold in some cases, but not all. Farmers whose preferences and production parameters are such that they already specialize in one contract type will remain specialized as they diversify. These farmers will also unambiguously reduce or eliminate the amount of contracts they sell if they become more diversified. Overall, it is likely that many farmers will continue to use CSA contracts for risk management, even when they become more diversified in crop production, but they may decrease the number of contracts sold.
Revisiting the Modeling Assumptions

The existence of a general equilibrium hinges on several assumptions that might not be grounded in reality. First, the model assumes perfect information, namely, that expected yields and associated yield distributions are known by farmers and consumers. In reality, it is unlikely that consumers know the farmers’ yield distribution. Second, the general equilibrium model assumes that all agents are price-takers and cannot exert market power; however, very little research has investigated the structure of CSA markets. Further, the establishment of a competitive market environment is required before certain empirical exercises can be undertaken; we discuss this in more detail in the next section. Third, our model assumes that farmers cannot shirk, but actual CSA contract terms are generally informal with very few CSA contracts stipulating the course of action should there be a full loss of farm production due to weather or disease. Assuming that the CSA contract market is a repeat game removes farmers’ incentives to voluntarily shirk by using suboptimal input levels, selling high priced commodities in the spot market instead of fulfilling their contractual obligations, or completely abandoning the crop. More generally, when contracts are incomplete, asymmetric information leads to moral hazard. Thus, future research is needed to determine if our modeling assumptions hold.

Finally, our model assumes that contracts are infinitely divisible and that consumers and farmers contract on individual products. In actuality, the farmers offer a contract that covers multiple goods and consumers must accept the entire bundle. So long as the bundle involves additively separable yields of each crop, the diversification hypothesis above holds. However, if farmers deliver excess yields of over-performing crops to compensate low yields of under-performing crops in the same basket, then the yield contracts are no longer additively separable. In this scenario, the farmer is using diversification to provide insurance on the yield contracts,
and this limiting her own risk management benefit from contracting. If non-separable yield contracts are the norm, then we would expect to see diversification be negatively correlated with the variety and scope of contract offerings.

**Empirical Research Challenges**

Future research is also needed to test the implications of the theoretical model. Although testing these implications is beyond the scope of this paper, we collected data from Farm Fresh Rhode Island to determine the prevalence of the various types of CSA contractual arrangements and further motivate the need for future research. Farm Fresh Rhode Island is a non-profit organization that promotes local food systems by maintaining an extensive online database of both CSA farms and non-CSA farms located in Rhode Island and neighboring states. Information pertaining to the types of CSA contracts offered by the farm was collected directly from Farm Fresh Rhode Island’s website (www.farmfreshri.org), the individual farm websites, or by calling the farm. Complete information was obtained for 226 CSA farms within a 150-mile radius of Providence, RI. We focus on farms in New England because it is where the first CSA programs in the United States were started (Wilkinson 2001) and thus CSA programs have a long established history in this area.

As shown in table 1, the majority of the farms (approximately 79%) offer yield contracts while approximately 9% offer weight contracts. A wide variety of products are provided by various CSA contracts and nearly all CSA contracts deliver vegetables. Other offered products include fruits, herbs, cut flowers and, to a lesser extent, eggs, dry goods and meat products. Most CSA farms in the sample offer more than one product category to its members, so it is difficult to categorize a particular CSA program as a “vegetable” or “fruit” CSA program. Table 1 also
suggests that there is a great deal of variability across CSA contracts. Table 2 shows the correlations between the various categories of product offerings.

While more research is needed to better understand the CSA contracting market, it is likely that researchers will face several challenges when engaging in empirical analysis. Perhaps the most important question that researchers must address is whether or not the assumption of perfect competition holds; as this is required for not only our theoretical model but also for certain empirical exercises. For example, many of the proposed testable propositions can be explored through the estimation of a hedonic pricing model. Hedonic pricing models attempt to decompose the prices paid by consumers into willingness to pay for various aspects or attributes of the good. Hence, firm-level data (data on prices charged by farms) can only be used to estimate hedonic models if price-cost markups are first eliminated (Feenstra 1995). In other words, the competitiveness of the market must be established. Internal tests of competitiveness on individual datasets are necessary due to the lack of studies exploring the structure of CSA contract markets. One noteworthy exception is the study presented in a working paper by Lass, Lavoie, and Fetter (2005), who found that CSA farms exert very little market power (only 2% of their potential market power). However, given the limited literature on market power, and since cost data are not readily available, the steps taken by Connolly and Klaiber (2014) (who follow Breshnahan and Reiss (1991)) could be replicated by researchers to determine if the CSA market in question has free entry (a characteristic of competitive markets) prior to conducting empirical work. Once competitive markets are established, then neither consumers nor producers will have sufficient market power to impact prices and hedonic pricing models can be used to carefully test theoretical propositions. Other factors that potentially affect the competitiveness of CSA markets include the location of the farm in proximity to urban areas as well as the ability to sell final
products produced on the farm through other channels; hence, these data should also be collected when conducting empirical work on CSA contracting.

CSA contracts are generally sold by the “share”; many CSA farms offer consumers the option of purchasing a “full” share or a “half” share. A “full” share is designed to provide enough products for 4-5 people and a “half” share is designed to provide enough products for 2-3 people. Given that a “share” is not an objective measure of expected quantity, obviously, there is likely a great deal of variability in the expected delivery quantities across CSA contracts. As shown in the theory section, yield contracts that have the same expected delivery quantities will have different equilibrium prices if the underlying yield distributions are different. Combining differences in (i) expected delivery quantities, (ii) products covered, (iii) price and yield covariances, and (iv) yield distributions, translates into variability in share prices across farmers which can be difficult to decompose, especially over a menu of contract prices.

In addition, obtaining information on expected delivery quantities is difficult in empirical work; while actually quantities delivered might be verified by diligent researchers, expected delivery quantities are generally just estimates provided by the farmer to potential consumers. Farmers may transmit this information to potential consumers via marketing materials (e.g., a website or CSA program brochure), but many farmers in our Farm Fresh dataset did not disclose any information regarding expected delivery quantities. Further, it is unclear how farmers that do report expected delivery quantities arrived at these values; perhaps they are the average quantities delivered in prior years or true forward-looking expectations based on plantings. None of the farms in our sample disclosed information on yield variability. An added empirical challenge from unobservable yields is the inability to measure price-yield covariance, revenue, or price-revenue covariance for a given crop.
CSA contracts terms or length of the “season” also tend to vary substantially from contract to contract. Thus, the number of deliveries and the length of time between deliveries are also likely to influence the prices consumers are willing to pay. In order to be able to compare the share prices of contracts across CSA with different lengths, researchers must attempt to construct a measure that standardizes the expected amount of products across the contract period. For example, the price per delivery could be constructed by dividing the share price by CSA length. However, constructing such a measure that attempts to standardize contract prices across farmers hinges on the underlying assumption that various contracts with different lengths deliver comparable products each week which is not likely to be the case.

Furthermore, the production practices of the farm might affect the prices consumers are willing to pay for the products covered by the CSA contract, and hence these production processes should also be accounted for in any empirical model. For example, consumers might be willing to pay premiums for products produced using organic practices, chemical-free farming practices, or integrated pest management techniques. Moreover, such practices might also influence the distribution of expected yields and hence affect final endowments and state prices. Separating an observed premium for a particular production process into the consumer preferences for the process and impacts on the yield distribution will be particularly challenging.

Other factors potentially affecting the CSA contract prices include the convenience associated with obtaining the deliveries and non-monetary costs of membership. The majority of CSA farms (at least in our sample) require members to pick up their share of the products at the farm. Other CSA farms require consumer to pick up the products at a farmers market or another location such as a church or place of business. Only two CSA farms in our Farm Fresh sample delivered the products directly to their members. Further, the concept of a CSA program is
grounded in linking consumers to their food source and farmers. As a result, CSA programs sometimes require members to “volunteer” on the farm, to help with planting, with weeding during the growing season or with the harvest. Mandatory work requirements for members, in some cases, may also impact the price of CSA contracts, all else equal.

**Conclusions**

In recent years, community supported agriculture programs have emerged as an important direct marketing strategy used by farmers in many states. CSA contracts let consumers buy directly a proportion of a farm’s production and thus are a key part of local food and farm-to-table movements, as well as a source of risk management for produce farmers. A variety of contract types have arisen to meet the needs of farmers and consumers, and we evaluate those contracts in the context of a two-period equilibrium model, using asset-pricing theory. In our theory, risk transfer has a significant effect on the contract price: share prices for pre-specified weights are more expensive than shares that deliver a proportion of the farm’s production because the consumer does not bear any of the farmer’s yield risk under the latter contractual arrangements.

Our CSA share pricing model indicates that the price differential between yield contracts and weight contracts is determined by two potentially competing factors, namely, the yield premium, which is due to the two types of contracts delivering different expected quantities, and the risk premium, which is due to the farm giving up price risk as a natural hedge for yield risk under weight share contracts. The risk premium is expected to be heterogeneous, both across farms, and across crops within farms. Further research is necessary to tease out these factors.

Adding to the complications of undertaking empirical work is the fact that many of the CSA contracts cover multiple commodities over various contract lengths. In our theory, we assumed the farmers contract on individual products; an abstraction from reality in which
consumers and producers are actually contracting on a basket of goods. Even with only one crop the covariance between prices and revenues, and therefore between contract payoffs, affects the producer’s optimal decision regarding the number and types of contracts to offer. Additional complexity arises in disentangling price relationships when contracts are over multiple crops. Farms frequently grow multiple commodities as a risk management strategy; any crops not perfectly correlated allow farms to benefit from diversification by reducing the variance of the farm’s revenues. Farmers may also trade off the risk management benefits of diversification with the risk management benefits of offering CSA contracts, especially if they are using diversification to insure the consumer against individual crop shortfalls in bundled yield contracts.

Clearly, further research is needed to understand how farmers utilize CSA contracting as a risk management strategy. This paper raises several empirical issues to be addressed in future research including market structure considerations, problems associated with obtaining information on actual and expected yields, the completeness of the contracts and agency problems. While our paper presents a theory of CSA contracting pricing, our model is a simplified view of the world. For example, we do not address how CSA contracting can ease credit constraints, how contracting impacts production decision or why consumers engage in CSA contracts. We ignored these elements to focus on the risk management features of CSA programs. Thus, more theoretical work is needed as well.

References


Farm Fresh Rhode Island. 2015. A Hub for Fresh, Healthy Food. Pawtucket, RI.  


Footnotes

1 For convenience and to differentiate them, we use ‘his’ and ‘her’ pronouns for consumers and farmers, respectively, without regard to actual gender.

2 The utility conditions ensure that expected utility-maximizing farmers limit the number of contracts they sell, to avoid a positive probability of being unable to meet their obligations. This, in turn, ensures the existence of the post-harvest general equilibrium for spot produce.
Table 1. CSA Farm and Contract Characteristics

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<tr>
<th>Variable</th>
<th>Frequency</th>
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<td><strong>Share Type</strong></td>
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<td>You-Pick Share</td>
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<td>Other</td>
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<td>Flowers</td>
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<td>Eggs</td>
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Note: Data were farm-level data for farms offering CSA located within a 150-mile radius of Providence, Rhode Island and listed on Farm Fresh Rhode Island’s website (www.farmfreshri.org).
Table 2. Correlations between CSA Product Offerings

<table>
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<th>Vegetables</th>
<th>Herbs</th>
<th>Flowers</th>
<th>Dry Goods</th>
<th>Dairy/Meat</th>
<th>Eggs</th>
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Note: Data were farm-level data for farms offering CSA located within a 150-mile radius of Providence, Rhode Island and listed on Farm Fresh Rhode Island’s website (www.farmfreshri.org)