Risk Management in the Cooperative Contract

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Ag marketing co-ops are important in risk management

But the typical cooperative does a much better job of helping their members manage some sorts of risk than it does others.

- Co-ops are good at reducing *marketing* risk, or idiosyncratic variation in prices observed within the course of a single season.
- Co-ops are not good at helping to manage *production* risk, which involves variation in yield over the course of several years.

Taking advantage of long-term relationships

By using dynamic incentives, the co-op could also provide a useful (though limited) form of insurance against production risk.

Introduction

Agricultural marketing cooperatives...

- **do** help to reduce price risk by pooling sales across time and space.
- **could** reduce production risk by making some payments to members on the basis of predetermined shares, rather than on quantities delivered ("patronage").
- **don't** use the mechanisms they seem to have available to help members deal with production risk.

Risks Under the Cooperative Contract

We consider four different sources of risk faced by agricultural producers:

1. Yield risk;
2. Quality risk;
3. Basis risk; and
4. Price risk.

Together, these will determine the total revenue generated by the farmer for a particular crop.

Risks Under the Cooperative Contract

Notation & Timing

Planting At the beginning of period t farmer i decides to devote m_{it} acres to the production of some particular commodity. The farmer invests a_{it} in inputs.

Harvest The farmer harvests at the end of the period, and realizes an average yield of q_{it} and quality θ_{it}.

Marketing Aggregate supply and demand yield a market price for the commodity in question of p_t—variation in these aggregates gives rise to price risk. But farmer i will receives a price $p_{it} = p_t + \theta_{it} + b_{it}$.

Risks Faced by the Producer

Putting it together

Farmer i's total revenue

$$y_{it} = p_{it} q_{it} m_{it} = (p_t + b_{it} + \theta_{it}) q_{it} m_{it}.$$

The farmer has some control over parts of this risk via his choices of m_{it} and inputs a_{it}. But idiosyncratic variation in basis (b_{it}), quality (q_{it}), quality (θ_{it}), and yield (q_{it}) implies that variation in the farmer's revenue will not be perfectly correlated with that of other farmers.

Effects of Pooling

Under very modest assumptions regarding the distribution of the idiosyncratic variables $(q_{it}, b_{it}, \theta_{it})$ the variation in *average* revenue across n farmers will be smaller than the average variation for a single farmer.

Total revenues for the cooperative will be

$$\bar{y}_t^n = \sum_{i=1}^{n} p_{it} q_{it} m_{it}.$$

With a law of large numbers, this implies that

$$\operatorname*{plim}_{n \to \infty} \frac{\bar{y}_t^n}{n} = \bar{y}_t.$$

Thus, by pooling revenues, the co-op can reduce the risks faced by every one of its members.

Effects of Pooling

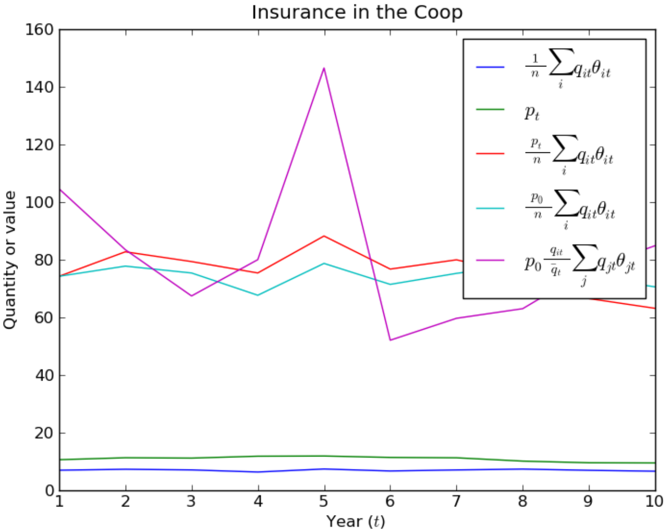
Cooperatives typically distribute their revenues in proportion to current year deliveries ("current patronage"); member i receives

$$\left(\frac{q_{it}m_{it}}{\sum_{j=1}^{n} q_{jt}m_{jt}}\right)\bar{y}_t^n.$$

While pooling within the cooperative effectively reduces variation in $\bar{y}_t^n$, it has no such effect on the variation of the share, which depends on q_{it}.

Relying on current patronage to divide revenues makes it impossible for the co-op to effectively share yield risk.

How the co-op insures basis and quality risk



Benchmark: Full risk-sharing in a cooperative

A marketing cooperative could completely insure its members against risks associated with idiosyncratic shocks to yield or production as well as risks associated with variation in prices, providing a sure ‘home’ for members’ production at a price determined in advance.

Benchmark: Full risk-sharing in a cooperative

Example

Consider a closed marketing cooperative. To fully insure members:

1. Each member would be assigned a *delivery target* in the cooperative. Member i's delivery target divided by the sum of all members' delivery targets would determine their *share* in the cooperative.
2. Members would commit to deliver all of their production to the coop—they would have, in effect, unlimited delivery rights, but not an *obligation* to deliver in the event of a production shortfall.
3. The cooperative would commit to distribute net revenues from the sale of all members' deliveries in direct proportion to members' initial shares.

Limits to Possible Insurance: Failures of Commitment

On the previous slide, the word "commit" appeared in two key places:

1. Members must commit to deliver all their production to the coop; and
2. The cooperative must in turn commit to distributing net revenues in proportion to initial shares.

But what if this commitment isn't feasible? It may not be possible to induce a member with unusually high production to share his windfall with other cooperative members; he may instead simply opt to market some of his production outside the cooperative.

The Optimal Contract with Limited Commitment

Stochastic Environment

1. Cooperative has n infinitely lived producers, indexed by $i = 1, 2, \ldots, n$.
2. Time is discrete, and is indexed by t.
3. At any date t some state of nature $s \in \mathcal{S}$ is realized (with $\mathcal{S}$ finite); given that the current period's state is s, the probability of the state next period being $r \in \mathcal{S}$ is given by $\pi_{sr} > 0$.

Preferences & Technology

1. Producer i derives momentary utility from consumption according to some function $u^i : \mathbb{R} \to \mathbb{R}$, and discounts future utility at a common rate $\beta \in [0, 1)$.
2. At each date, producer i chooses a stochastic production technology such that if the current state is s and the producer invests a, then next period the technology returns some quantity $f^i_{sr}(a)$ in the event that the subsequent state is r.
3. We assume that each of the functions f^i_{sr} is non-decreasing, concave, and continuously differentiable.

Limited commitment

Producers can agree to participate in a scheme involving mutual insurance, but the scope of this insurance is limited by the fact that after any history each producer has the option of reneging on any proposed insurance transfers.

In the event that a producer i which has saved a^i units of the consumption good reneges in state s, he is assumed to obtain a discounted, expected utility given by the continuously differentiable function $Z_s^i(a^i)$.

Thus, any 'sustainable' insurance scheme must guarantee that in state s every producer i having saved a^i obtains at least $Z_s^i(a^i)$ utils under the proposed insurance scheme.

A Dynamic Program

Let U_s^i be the discounted expected utility for producers i in state s.

The complete set of necessary state variables is

- The current state of nature s;
- Promised discounted, expected utilities $\mathbf{U}_s^{-n} = \{U_s^i\}_{i=1}^{n-1}$;
- The resources available to all the members of the cooperative at the beginning of the period, z.

Choice variables in the programming problem are

- Consumption assignments c^i for $i = 1, \ldots, n$;
- Continuation utilities U_r^i for each possible state r in the next period; and
- An assignment of both technologies $\{f_{sr}^i\}$ and of investments a^i for each producer.

Bellman's equation

Objective Function

The value function for producer n can now be written to depend on the current target utilities and collective resources: $U_s^n(U_s^1, \ldots, U_s^{n-1}; z)$. Then the dynamic programming problem is

$$U_s^n(\mathbf{U}_s^{-n}; z) = \max_{(\mathbf{U}_r^{-n})_{r \in \mathcal{S}}, (c^i, (f_{sr}^i)_{r \in \mathcal{S}}, a^i)_{i=1}^n} u_n(c^n) + \beta \sum_{r \in \mathcal{S}} \pi_{sr} U_r^n \left(\mathbf{U}_r^{-n}; \sum_{i=1}^n f_{sr}^i(a^i) \right)$$

subject to...

Bellman's equation

Constraints

...the following constraints (Lagrange multipliers on left):

$$\mu: \quad \sum_{i=1}^{n}(a^i + c^i) \le z$$

$$\lambda^i: \quad u_i(c^i) + \beta \sum_{r \in \mathcal{S}} \pi_{sr} U_r^i \ge U_s^i$$

$$\beta\lambda^i \pi_{sr}\phi_r^i: \quad U_r^i \ge Z_r^i(a^i)$$

$$\beta\pi_{sr}\phi_r^n: \quad U_r^n\left(\mathbf{U}_r^{-n}; \sum_{i=1}^{n} f_{sr}^i(a^i)\right) \ge Z_r^n(a^n).$$

First order conditions

The key first-order from this problem are

$$\frac{u_n'(c^n)}{u_i'(c^i)} = \lambda^i, \quad \forall i \neq n, \tag{1}$$

$$\lambda_r^i = \lambda^i \frac{1+\phi_r^i}{1+\phi_r^n}, \forall r \in S, \forall i \neq n, \tag{2}$$

where $\lambda_r^i \equiv \partial U_r^n / \partial U_r^i$ (by the envelope condition this is equal to next period's ratio of marginal utilities between producers n and i), and

$$u_i'(c^i) = \beta \sum_{r \in \mathcal{S}} \pi_{sr} \left[{f_{sr}^i}'(a^i) u_i'(c_r^i) \right] + \beta \sum_{r \in \mathcal{S}} \pi_{sr} \phi_r^i \left[{f_{sr}^i}'(a^i) u_i'(c_r^i) - {Z'}_r^i(a_s^i) \right] \tag{3}$$

NB: Betty's question about coordinating group investment

Solution

It's not difficult to show that one can give a complete characterization of the optimal sharing rule under limited commitment in terms of the evolution of the Lagrange multipliers $\{\lambda^i\}$.

The multiplier λ^i is important.

With log utility, λ^i would be proportional to a producer's share of co-op revenue.

Optimal Updating rule

A producer i starts the period with some initial value of λ^i:

1. Leave the new value of λ^i equal to the old, unless...
2. The old value of λ^i isn't high enough to deter some producer from wanting to cheat. In this case, *increase* λ^i *just* enough to keep him honest. Or...
3. Some *other* producer j wants to cheat. Then increase λ^j by just enough to keep j honest, and decrease others' λs to finance j's increased share.
4. Go on to the next period, using the (possibly) updated values of the $\{\lambda^i\}$.

Implementing the Optimal Contract with Limited Commitment

We've devised an optimal intertemporal sharing rule which would provide maximal risk-sharing within a cooperative facing limited commitment.

However, the rule we devised is specified in terms of consumption and investment allocations, and in terms of promised utilities. It may not be practical or natural to write the membership agreement, by-laws, and so on for the cooperative in these terms.

The key to mapping between the jargon of agricultural cooperatives and the model we've outlined: We need to find some counterpart to the quantities λ^i discussed above.

Accumulated patronage points

The history of the ith producer's patronage is summarized by the multiplier λ^i.

So let's simply imagine computing the updating rule for λ^i, but calling this quantity the producer's "accumulated patronage points."

This is simply an accounting mechanism which would allow the cooperative to keep track of the history of members' deliveries, and in particular to keep track of the extent to which a given member has subsidized others in the past, so as to reward that same member in the future.

Some key implementation points

- "Accumulated patronage points" for farmer i in state s correspond to the quantity λ_s^i.
- When farmers have logarithmic utility functions, then farmer i will receive a share of total cooperative revenue in state s equal to
$$\sigma_s^i = \frac{\lambda_s^i}{\sum_{j=1}^n \lambda_s^j}.$$
- Producers with more accumulated patronage receive higher compensation for delivery of some fixed amount than would producers with less accumulated patronage.

Some key implementation points

Continued

- Because each farmer's share of current revenue depends on his *accumulated* patronage, he is protected against current production shortfalls. Since the division of cooperative revenues depends on these accumulated points, he won't be seriously hurt by a bad idiosyncratic shock.
- However, since the subsidy he receives from others may result in new patronage points for *them*, his share of total accumulated patronage points will fall, resulting in a smaller share of total revenues for the farmer in the future.

Some key implementation points

Continued

- Anyone can join the cooperative, simply by delivering output, but a "new" producer has an "accumulated patronage" which will be somewhat less than the total share of his deliveries to the cooperative in the year he joins. Since he thus provides an initial subsidy to existing members, he will be welcomed. In turn, a new member has an incentive to join (even though he'll be compensated for less than his full deliveries) because of the future benefits of risk reduction he receives by virtue of joining the cooperative.
- Every farmer has some 'delivery target'; the value of this target depends on his accumulated 'patronage points', which in turn depend on historical deliveries. New members start with a delivery target of zero, so their initial delivery is imediately rewarded with some patronage points.

Some key implementation points

Continued

- If the cooperative has enough members, then every farmer is fully insured (in the current period) against failure to reach his delivery target.
- A farmer receives additional 'patronage points' whenever his deliveries exceed his delivery target (and receives no additional points otherwise).
- The cooperative markets total deliveries $\bar{q}_t = \sum_i m_{it} q_{it}$, realizing an average price p_t.
- The cooperative distributes τ_{it} to the ith farmer; this distribution is equal to total revenue $p_t \bar{q}_t$ times the farmer's share of total patronage points.

Summary

- Presently marketing coops do a good job of insuring some risks, but not others—in particular, they don't help insure production risk.
- By constructing dynamic rewards and punishments related to the history of deliveries to the co-op, it is possible to at least partially insure production risk, and increase the value of the co-op.
- The dynamic scheme also makes it easy to manage a changing membership—since equity follows patronage, new members can join and build equity, while others can retire, and have their equity slowly dwindle.

Relation to Two-Level Insurance

The idea of rewriting the cooperative contract to allow for sharing of production risk within the co-op can be seen either as

- An alternative to trying to provide individual insurance contracts; or
- A description of de facto informal arrangements that may already prevail within the co-op.

Closing Thoughts

- Are we sure that co-op members don't already do an adequate job of sharing risk, perhaps informally or via other mechanisms?
- If a scheme for sharing production risk doesn't exist, there must be a reason. It'd be nice to know this reason before we design a "solution" to the "problem".
- Even if co-ops just eliminate basis and quality risk, that can *increase* demand for insurance against co-op level production variation.
- Low production doesn't necessarily mean low revenue—depends on elasticity of supply curve.

Betty's Questions

Does a group index insurance benefit from the existence of a lower level contract?

Can construct an example where demand for insurance for group aggregate increases when group insures away yield risk. Don't know how general result is; seems to require increasing relative risk aversion.

Betty's Questions

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eciprocally, does a group practicing mutual insurance benefit from the "group" aspect of index insurance in terms of insurance value?

In the dynamic limited commitment model, yes. Insuring the group rather than individuals improves intra-group insurance (all members get more surplus from group relative to outside option).

Betty's Questions

Group decisions different from sum of individual?

Is there merit to have a group decision as opposed to the group being simply the aggregation of voluntary subscriptions?

Yes. For example, allocations of storage or investment will be collectively decided in the dynamic limited commitment model in a way which differs from what would obtain for individuals.

Betty's Questions

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