Determination of Optimal Forward Contracting for a Peanut Buyer-Sheller

by

Robert W. Dubman and Bill R. Miller

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First handlers who assume ownership of agricultural commodities face risks both on acquiring the commodity from farmers and on selling to further processors or retailers. Since the 1980 drought, peanut buyers-shellers have feared the uncertainty in supply of farm peanuts bought by the firm. Prior to the fall harvest shellers typically forward contract, with further processors or retailers, to deliver a percentage of expected farm purchases. This guarantees a fixed price on that percentage and shelters the sheller from later price changes. However, if the percentage of peanuts forward contracted is high and farm production is low, the sheller could be short and thus unable to meet delivery contracts. Further, if all shellers are short, peanuts bought on the open market to alleviate a large shortage are likely to be expensive. Prices effectively doubled after the 1980 drought cut production. The sheller must balance the certainty of a forward contract price against the risk of not acquiring the peanuts to fulfill the forward contracts. This paper presents a method of risk analysis and a case study for determining the long run percentage of forward contracted sales that optimizes the sheller's expected utility under the 1985 peanut program.

Techniques that handle risk in input supplies have been presented by many authors although none is suitable for the situation faced by a peanut sheller in which prices are also uncertain. Charnes and Cooper developed chance-constrained programming in which input supply is estimated on the low side in order to assure a feasible solution. However, no method of connecting the utility function of an individual with how low a particular risk-averse individual would estimate input supply has been devised. Paris tried symmetric quadratic programming as a way to introduce risk in inputs into Freund's quadratic programming model. Paris's method has underlying theoretical difficulties that make it unusable. Lambert and McCarl use direct nonlinear maximization of utility to analyze risky prices and suggest that risky inputs could also be handled in their model. The same problems of relating risk to supply that occur in chance-constrained programming would occur. The method used in this paper which includes both risky prices and inputs is a variation of the stochastic programming model by Gaither that has been adapted to include expected utility.

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Temporal Buying and Selling Activities of Peanut Shelling

Peanuts are marketed on a two-tiered pricing system with import barriers and farmer marketing quotas on peanuts grown for domestic consumption. "Quota" peanuts can be sold domestically and have relatively high (probably above a free market price) loan support prices. "Additional" peanuts must be crushed or exported and have a low (probably below a free market price) loan support price at the crush level. No limits are imposed on farmers' production of additional peanuts.

The activities of a peanut sheller are dependent on the time dimension of the crop year. Peanuts from one season are marketed for approximately twenty months. For analytical purposes, these twenty months are divided into three periods. The first period is the growing season (January to August) of the current year. Farm purchase contracts are signed during this period and decisions about forward contracting new-crop peanuts to be sold in the next two periods must also be made.

The second period is the harvest season (September to December) of the current year. This is the only period in which the sheller receives new-crop peanuts from the farm. The third period is from January to August of the next year. Peanut stocks are depleted in preparation for the next crop. During the January-August period peanuts may be bought from other handlers or redeemed from the Commodity Credit Corporation (CCC). Old and new-crop sales are made and shelling and storage activities occur during the period. Shelling operations taper and completely shut down toward August.

Peanuts from a particular crop year can be physically delivered only after harvest, in the second and third period. The sheller typically forward contracts during the first period for peanuts he can deliver in the second and third period. Sales and storage beyond these periods are possible but discouraged due to storage costs and uncertainty in market conditions two or more years ahead. The amount to forward contract is the focus of this paper.

The marketing variables involved in the intertemporal flow of peanuts are presented in Table 1 via a pro forma income statement. These variables will become activities in the objective function of a linear programming tableau. The variables are divided into marketing activities for additionals, quotas, buybacks, and farm purchases. Additional and quota activities are identical in function and these will be discussed simultaneously followed by discussions of the buyback option, farm purchases, and fixed costs.

Current crop year (new crop) peanuts can be sold in the second and third periods. The sales can be either by forward contracts signed in the first period or by an immediate cash transaction. Similarly, peanuts can be bought in the same manner. However, two extra buy-in activities are listed to distinguish the high buy-in prices that might occur during a year of low farm production. The 1980 drought was an instance of this

Table 1. PRO FORMA INCOME STATEMENT FOR A PEANUT BUYER-SHELLER

Marketing Activities	Shelled Tons	Ave Unit Price or Cost	Revenues and Costs	
Additional Sales				$32,000,483.00
Forward Contract for Sept-Dec delivery	27437	$534.00	$14,651,358.00	
Cash Sept-Dec	27738	$548.50	$15,214,293.00	
Forward Contract for Jan-Aug delivery	5488	$389.00	$2,134,832.00	
Cash Jan-Aug	0	$361.50	$0.00	
Additional Buy-ins				($2,003,386.01)
Forward Contract for Sept-Dec delivery	0	($539.34)	$0.00	
Cash Sept-Dec	0	($553.99)	$0.00	
Cash Sept-Dec Drought	0	($1,107.97)	$0.00	
Forward Contract for Jan-Aug delivery	0	($392.89)	$0.00	
Cash Jan-Aug	5487	($365.12)	($2,003,386.01)	
Cash Jan-Aug Drought	0	($730.23)	$0.00	
Additional Carryovers				$0.00
Sept-Dec to Jan-Aug	0	$15.00	$0.00	
Jan-Aug to Ending Inventory	0	$30.00	$0.00	
Beginning Additional Inventory				($4,500.00)
Carry Sept-Dec	300	($15.00)	($4,500.00)	
Carry Jan-Aug	0	($30.00)	$0.00	
Carry One Year	0	($45.00)	$0.00	
Handle Additional Farm Deliveries	54875	($80.00)	($4,390,000.00)	($4,390,000.00)
Quota Sales				$84,220,000.00
Forward Contract for Sept-Dec delivery	67000	$715.00	$47,905,000.00	
Cash Sept-Dec	0	$606.00	$0.00	
Forward Contract for Jan-Aug delivery	0	$692.50	$0.00	
Cash Jan-Aug	54000	$672.50	$36,315,000.00	
Quota Buy-ins				($6,120,600.00)
Forward Contract for Sept-Dec delivery	0	($722.15)	$0.00	
Cash Sept-Dec	10000	($612.06)	($6,120,600.00)	
Cash Sept-Dec Drought	0	($1,224.12)	$0.00	
Forward Contract for Jan-Aug delivery	0	($699.43)	$0.00	
Cash Jan-Aug	0	($679.23)	$0.00	
Cash Jan-Aug Drought	0	($1,358.45)	$0.00	
Quota Carryovers				$0.00
Sept-dec to Jan-Aug	54000	$0.00	$0.00	
Jan-Aug to Ending Inventory	0	($30.00)	$0.00	
Beginning Quota Inventory				($165,000.00)
Carry Sept-Dec	11000	($15.00)	($165,000.00)	
Carry Jan-Aug	0	($30.00)	$0.00	
Carry One Year	0	($45.00)	$0.00	
Handle Quota Farm Deliveries	100000	($80.00)	($8,000,000.00)	($8,000,000.00)
Buy-Backs Purchased				$0.00
Added to Quota	0	($550.00)	$0.00	
Substituted for Quota	0	($520.00)	$0.00	
Farm Purchases				($77,824,375.00)
Quotas	100000	($556.00)	($55,600,000.00)	
Contracted Additionals	54875	($405.00)	($22,224,375.00)	
Uncontracted Additionals	0	($410.00)	$0.00	
Fixed Costs				($10,000,000.00)
Profits				$7,712,621.99

when the cash buy-in prices were roughly double the usual prices. Forward contract prices are fixed while cash prices tend to be volatile.

Unsold peanuts can be held from one period to the next. Second period peanuts can be put in storage and carried over to the third period. Third period peanuts can be placed into ending inventory and sold in the next crop year.

Inventory left over from the previous crop can be sold in the second or third periods. These can also be held one year and placed in the ending inventory to be sold as old crop in the next crop year. The ending inventory of one crop year becomes the beginning inventory of the next crop year. The inventories are the connection between crop years.

Handling charges are assessed to bring the farm peanuts to the shelling plant. These variable costs include transportation, inspection, grading, weighing, short-term storage, buying point commissions, and shelling costs. The variable costs of peanut shelling are mostly labor and electricity and are included in the farm delivery charges. Fixed costs such as interest on buildings and equipment, management costs, fixed labor costs, insurance, and depreciation are included separately as the last item in the income statement to calculate profits.

Buyback Activities

Buyback of peanuts is a provision of the peanut program that allows additional peanuts to be sold domestically if certain conditions are met. Buybacks occur during the harvesting period since only additional peanuts delivered by farmers may be bought back. Buyback means that peanuts are redeemed from the CCC additional loan program within 48 hours of delivery on permission of the farmer. The quota loan rate must be paid which yields profits to the additional peanut loan program. The pool profits are distributed to farmers; however, recent agreements between farmers and shellers have allowed shellers to share in some or all of the pool profits. By doing this the sheller could purchase buybacks at a net price per ton that is less than the quota loan rate.

Two types of buyback activities are distinguished. The first activity simply adds to the quota available to the firm. If the sheller feels it can sell more peanuts on the domestic market than were originally contracted with its farmers then "add to quota" buybacks are used. Note that quotas are farmer marketing limits and not sheller marketing limits. By using the buyback option, the firm can market more domestic peanuts than its contracted farmers can produce as domestic quotas.

The second buyback activity leaves the amount of quota available to the firm unchanged but reduces the amount of additionals. The sheller buys back additional peanuts and then instructs the farmer to place an equivalent amount of quota peanuts into the quota loan. In effect, additional peanuts are substituted for quotas. Substitute buy-backs may be used when the firm has an excess of additionals and would lose less money by converting them to quotas, or, when the net price from pool profit sharing means that buyback additionals can be sold more profitably than quotas.

According to classical theory, the firm would try to determine the combination of the above activities that maximize profits. The constraints that apply to the activities complete a linear programming model that might approximate conditions facing the firm. The constraints that hold for the 1985 peanut program are presented below.

Constraints on the Peanut Buyer-Sheller

The sheller traditionally takes delivery of all peanuts produced by his contracted farmers. The sheller must take all contracted quota and contracted additional peanuts if they are produced but has an option of directing uncontracted additional peanuts into the loan. Farm production is uncertain and this leads to stochastic availability of both quota and additional peanuts in the programming model.

Buybacks must come from farm production. Therefore, contracted additionals bought back must be less than contracted additionals produced. Similarly, uncontracted additionals bought back must be less than uncontracted additionals produced. Additional peanuts delivered to the plant must equal contracted additionals minus the contracted additionals diverted to quotas.

All additional peanuts supplied to the firm in the January-August period from buy-ins, carryover, and beginning inventory must be sold in that period or placed in ending inventory. All additional peanuts supplied to the firm in the September-December period from farm deliveries, beginning inventory or buy-ins must be sold in the second period or transferred as old-crop to the third period (or next crop year). New-crop quota peanuts delivered to the firm must come from contracted farm quotas or from buybacks. All old crop quota peanuts supplied to the firm from beginning inventory, or second period carryovers or buy-ins must be sold or placed in ending inventory. All quota peanuts supplied to the firm in the second period come from new crop farm deliveries, beginning inventory, or buy-ins and must be sold in the second period or transferred to the third period.

The beginning inventories of both quotas and additionals are pre-determined values set by the firm in the previous crop year. Additional beginning inventory should be small because of a November 15 deadline for exporting old crop peanuts.

Shelling firms want to limit the size of ending inventories to reduce their exposure to potential price changes in future years. Storage and interest costs must also be paid. The storage life of peanuts can be several years under proper conditions although peanuts stored for long periods will suffer physical deterioration.

Plant capacity is a possible limiting constraint on the firm's ability to expand operations in a given year. Most shelling firms tend to have excess capacity. The plants are not run to capacity except perhaps during the harvest period.

A more likely constraint on firm expansion is the firm's market share of farm quotas. A zero-sum game occurs in an industry with raw product quota limits. In order for one firm to increase its market share another firm must lose. Each sheller has excess shelling capacity which suggests a common market strategy for all shellers. Apparently, each attempts to maximize market share of farm quotas. However, this can lead to damaging price wars as evidenced from the 1984 crop. If a firm is willing to take a loss as some firms did during the 1984-85 season, it may increase or at least protect its market share. A fear of a price war appears to set a limit on the amount of quota peanuts a large firm can expect to buy at prevailing prices.

A drought or some other catastrophe will probably be the reason a large amount of peanuts need to be bought-in. The same conditions that caused the single sheller's shortage will likely have affected all other shellers. In the model, buy-ins at prevailing market prices have been limited to be less than ten percent of actual farm production for both additionals and quotas. This was the experience of the case study firm.

The percent forward contracted is also a constraint in this model. The sheller's desire to forward contract is expressed as a requirement to limit forward contracts to a specified percentage of expected farm production of both quotas and additionals. An ad hoc rule is currently used by the case study sheller to decide the limit of forward contracting. The riskiness and optimal percentage of forward sales to contract is being investigated in this study.

The linear programming model used for this study is structured such that stochastic variables can appear only in the resource vector and the objective function. The technical matrix is fixed and consists of only "+1", "-1", or zero entries. Market prices in the objective function are subject to random fluctuations. Uncertain values in the right hand side (rhs) consist of the quota, contracted additional, and uncontracted additional farm production plus the amount of peanuts the firm can buy-in at prevailing market prices. Fixed non-zero values in the rhs include the beginning inventories, the limits on ending inventories, limits on forward contracts, the market share of quotas, and plant capacity.

The sheller has the opportunity to alter some of the fixed values in the rhs before the season begins. These variables and still other variables that determine the rhs are referred to as exogenous management decision variables. Plant size, farm contracting ratio of quotas to additionals, size of beginning and ending inventories, and percentage to forward contract for delivery are examples of exogenous management decision variables. The sheller wants to set these variables to values that are most likely to maximize his profits at the end of the season while considering the risks involved.

Risk Considerations

Shellers must contract with farmers during the growing season to be assured of an adequate supply of quota and additional peanuts. Decisions on the amount of peanuts to contract for forward delivery must be made months before the peanuts are purchased. The typical farm contract expresses contracted additional tons as a percentage of quotas. In this case study a 2 to 1 contract was analyzed which means that for every two tons of quotas the farmer delivers, the sheller will accept at most one ton of additionals. Any peanuts produced by the farmer beyond the contracted levels become uncontracted additionals and can only be bought-back or crushed.

The nature of the farm contract is considered a major source of input uncertainty faced by shellers. Many farm contracts are written so that farmers are not required under penalty of law to deliver the contracted peanuts. This is referred to as an "act of nature" clause and is a historical carryover from before 1981 when contracts were required to be on Commodity Credit Corporation Form 1005 which was lenient towards farmers and did not require delivery. Competitive pressure among shellers has kept this non-delivery clause intact. Farmers would much rather sign a contract that does not require delivery. If one sheller offers such a contract other shellers must follow or lose business. Shellers are left vulnerable because they are required to deliver on any forward contracts of shelled peanuts they make (exceptions that occurred during the 1980 drought required litigation), but farmers are not required to deliver on contracts with the sheller. From the shelling industry's viewpoint the farm contract is very one-sided and risky; shellers bear all the contract risk.

Risk in peanut marketing is centered on, but not restricted to, additional peanuts. Farmers deliver their quota peanuts with the higher support price first; thus, farmers will probably produce their quota. The uncertainty in farm deliveries falls on the additional peanuts since they are delivered last. Also, quota prices are stabilized by the support program; prices of additional peanuts are determined by risky world market conditions. The additional loan support price is set at the value of crush peanuts which is well below current world price levels. The estimated variances of prices in the analysis found additional prices to have a much larger range than the quota prices.

Buybacks are a source of peanuts equivalent to quotas to fulfill a quota forward contract shortage, but no equivalent alternative source is available for additional contract shortages. Quotas could be exported as additionals, but the price differential would be prohibitive.

No futures market exists for peanuts and possiblities for such a development are small (Miller, Smith, and Williams). Also, no government sponsored stocks are held between years to mitigate price and yield fluctuations. The combination of input supply risk and price risk in peanut marketing has stimulated a search for a technique to manage these risks.

Theory and Methods

Uncertainty in inputs and uncertainty in prices have been investigated by many researchers, but these techniques have been found unsuitable for analyzing significant sources of simultaneous price and input supply risk. The method in this study can be described as stochastic linear programming in which the goal is to maximize the expected utility of the sheller with respect to exogenous management decision variables. The concepts behind the method are discussed below.

The distribution of farm additional peanut deliveries depends on the contracted amount of quotas, the acres planted by farmers to meet the contract, and yield per acre. Since additionals are delivered last, the distribution of the additional farm deliveries is some part of the right tail of the distribution of all farm deliveries of peanuts. The tonnage of additionals contracted with farmers is the upper limit of expected additional farm deliveries. However, the expectation of all peanuts delivered is a function of the number of acres planted by farmers. Farm contracts are written in tons and the farmer decides the number of acres to plant. Farmers tend to plant an excess number of acres in order to have more assurance of producing the contracted quota tonnage. Historical evidence for Georgia suggests that farmers have consistently over-planted quota contract obligations. Shellers recognize this behavior and adjust their expectations of deliveries accordingly.

The minimum cost of acquiring peanuts to fill the forward contracts in case farm yields are low are shown for three forward contracting levels in figure 1. The cost curve for 100 percent forward contracted is the highest and indicates that a shortage at this level could be very costly to make up. The line is kinked to show that buy-in prices will increase significantly if a severe drought limited farm production. Peanut production is centered in the southeastern states and a large shelling firm will likely have farms scattered throughout the region. If the sheller's farms have a low production year, national peanut production will also likely be down. The cost of handling excess additional peanuts is low, since peanuts can be put into the loan. Thus, the cost curves are level on the right.

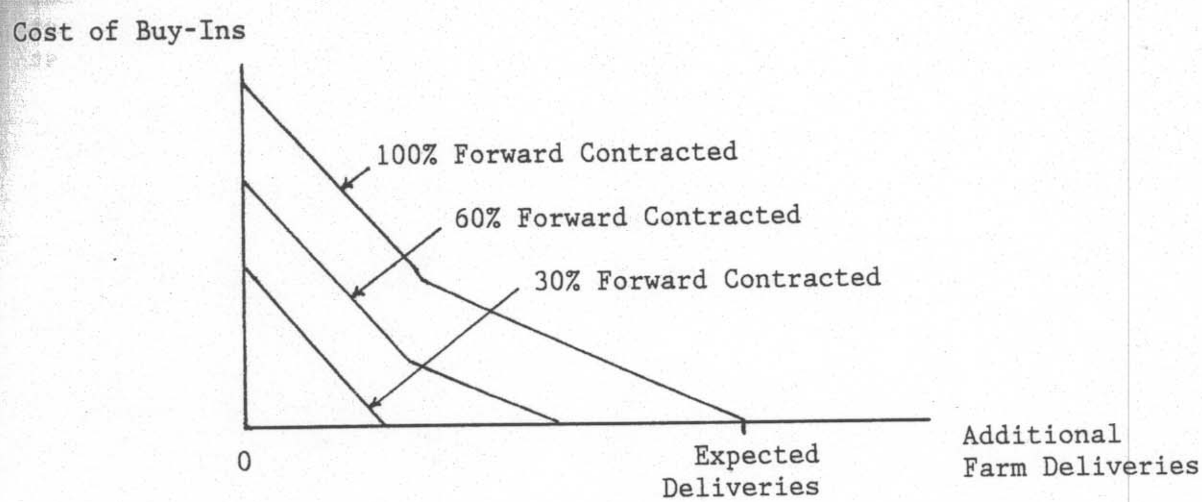

Figure 1: Cost of Buy-Ins Needed to Fill Forward Contracts.

An expected cost of acquiring the peanuts at each forward contracting level can be calculated with the distribution of farm deliveries and the cost curves. Expected cost $= \int_0^\infty C(x)*f(x)dx$ where C(x) is the cost curve and f(x) is the probability of each cost occurring. This probability is derived from the distribution of farm deliveries.

The expected cost of acquiring peanuts at each forward contract level is presented in figure 2. Note that a sheller may contract more than 100% of expected farm production although this would have a high expected cost. The more a sheller forward contracts, the higher will be the expected cost of fulfilling these contracts.

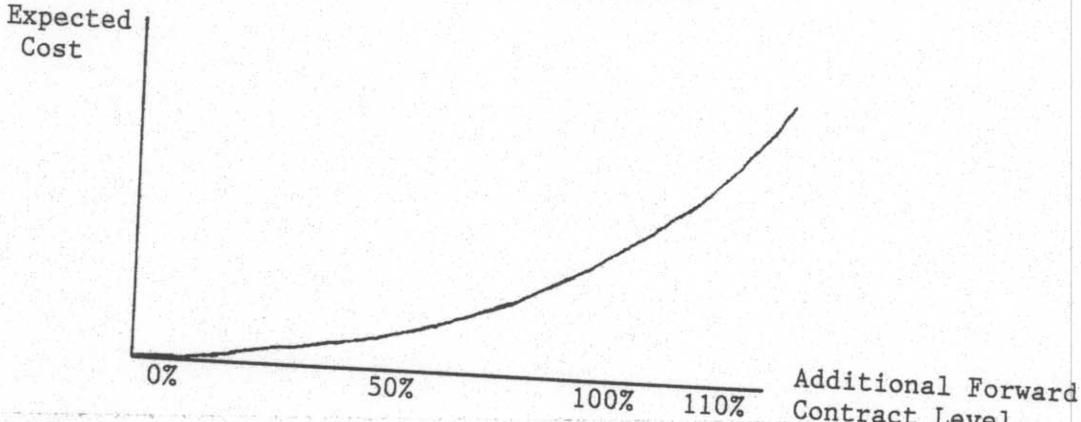

Figure 2: Expected Cost of Acquiring Peanuts to Fill Contracts.

The underlying theory of the effect of forward contracting on costs has been presented above. However, shellers, like individuals, can have utility functions and desire to maximize utility. The next step in the method is to maximize the expected utility of the firm.

The utility function of a firm has many of the properties of an indivivdual's utility function, such as a positive but decreasing marginal utility of money. An advantage of using a firm's utility function is that several points on the curve might be identified. The firm ceases to exist at a bankruptcy level of profits and will have negative infinite utility at that point. The marginal utility of profit is expected to decline significantly after reaching a target level of profits (Thompson). For example, profits considered excessive may attract unwanted attention. For this case study the generally accepted negative exponential utility function presented by Freund was used and tempered by suggestions from the sheller in the case study. Any continuous utility function with the above properties could have been acceptable. The functional form is insignificant for the intermediate points.

The firm's expected utility of profit is assumed to be a function of the firm's profit distribution. The profit distribution includes the distribution of farm deliveries mentioned above plus the distribution of prices. The stochastic prices include cash sales and buy-ins of additional and quota peanuts in both time periods of the crop year. If the model is run during period one (January to August), forward contract prices are by definition fixed. The tableau presented earlier is used with stochastic linear programming to reproduce risky conditions that might occur at random throughout periods two and three. Prices, farm yields, and acres planted are subject to random variations and the sheller can decide, with its utility function and the risky distribution of profits, the level of the exogenous management decision variables that maximize expected utility.

The steps in our method are as follows. First, build a deterministic profit maximizing linear programming model and determine the stochastic variables. Estimate expected values and a variance-covariance matrix for these stochastic variables. Generate correlated random normal deviates using the expected values and estimated covariance matrix. Set the exogenous management decision variable (the percent forward contracted in this study) to a chosen value. Solve the model repeatedly with the randomly generated prices and rhs. This will generate a distribution of profits. These profits can then be combined with a utility function to determine an expected utility. Set the exogenous management decision variable to another value and calculate the profit distribution and expected utility again. By repeating the above process a finite number of iterations, the value of the exogenous management decision variable that maximizes expected utility can be found.

Relaxing a binding constraint in the rhs in a linear programming profit maximization problem will never decrease profits; a maximum will never be found. However, the method described above includes the distributions of price and input supply, and the shellers risk preferences. Thus, a maximum expected utility can exist.

A Case Study

As an example we modeled a large peanut sheller from the southeast. The expected prices used are those presented in Table 1. Experts in peanut marketing were polled to get these expected prices. The variance-covariance matrix was estimated with a combination of historical data and subjective estimates for Georgia yields and acres planted and the variances and covariances of prices and yields.

Values of the fixed variables in the model were as follows. Quota farm contract level was given at 112,000 tons. A 2 to 1 contract ratio implied a maximum of 56,000 tons of additionals were contracted with farmers. Market share of quotas from farms was 140,000 tons and plant capacity of both quotas and additionals was given at 225,000 tons. Limits on ending inventories of quotas and additionals were 11,000 tons and 300 tons, respectively. The beginning inventories of quotas and additionals were also set at 11,000 and 300 tons, respectively.

A negative exponential utility function was assumed. The risk aversion coefficient was set at $8x10^{-8}$ to be consistent with the level of income of a large sheller. The function is: Utility= $1\text{-}e^{-(8x10^{-8})x}$ profit. This utility function is consistent with information provided by the case study sheller. Indications are that some shellers are very risk averse and and would prefer not to hold any unsold peanuts. This utility function reflects strong risk aversion.

The computing was accomplished with a computer program written by the authors specifically for this task. A revised simplex algorithm using the product form of the inverse was combined with a correlated random number generator and an algorithm to determine the expected utilities. The program was written in vectorized fortran for use on a Cyber205 computer. A microcomputer version is being planned.

The results are presented graphically in Figure 3. The percentage of expected farm production forward contracted during the marketing year that maximizes expected utility is 60 percent. Note that the expected profits at 70, 80, and 90 percent forward contracted are higher than at 60 percent. Using a maximum expected utility rule gives a lower percentage than would maximizing expected profits.

The results are further explained in Figure 4 which shows the 95 percent confidence region of profits along with the expected profits for each contracting level. The profit distributions are not symmetric. High forward contracting percentages can result in large losses. The lower confidence curve gives the worst scenario case such as the major drought of 1980. If the sheller had contracted 100 percent of its expected farm production it would have lost $12 million in that year. The chances of large losses will cause the risk-averse sheller to avoid the high forward contracting percentages.

Summary and Conclusions

A method and a case study of risk analysis for determining the value of exogenous management decision variables that maximize expected utility have been presented. The percentage forward contracted for a marketing year was investigated and for the case study firm was found to maximize expected utility at 60 percent of annual deliveries. This was less than the percentage forward contracted that generated maximum expected profit. The technique generated results close to those experienced by the case study sheller and generated a rule for forward contracting that was at the lower limit of observed amounts that are normally contracted by the firm.

Further research includes investigating the other exogenous management decision variables, applying different utility functions, and calibrating the model and data. The method is not unique to peanut shelling and could be applied to first handlers of other agricultural commodities.

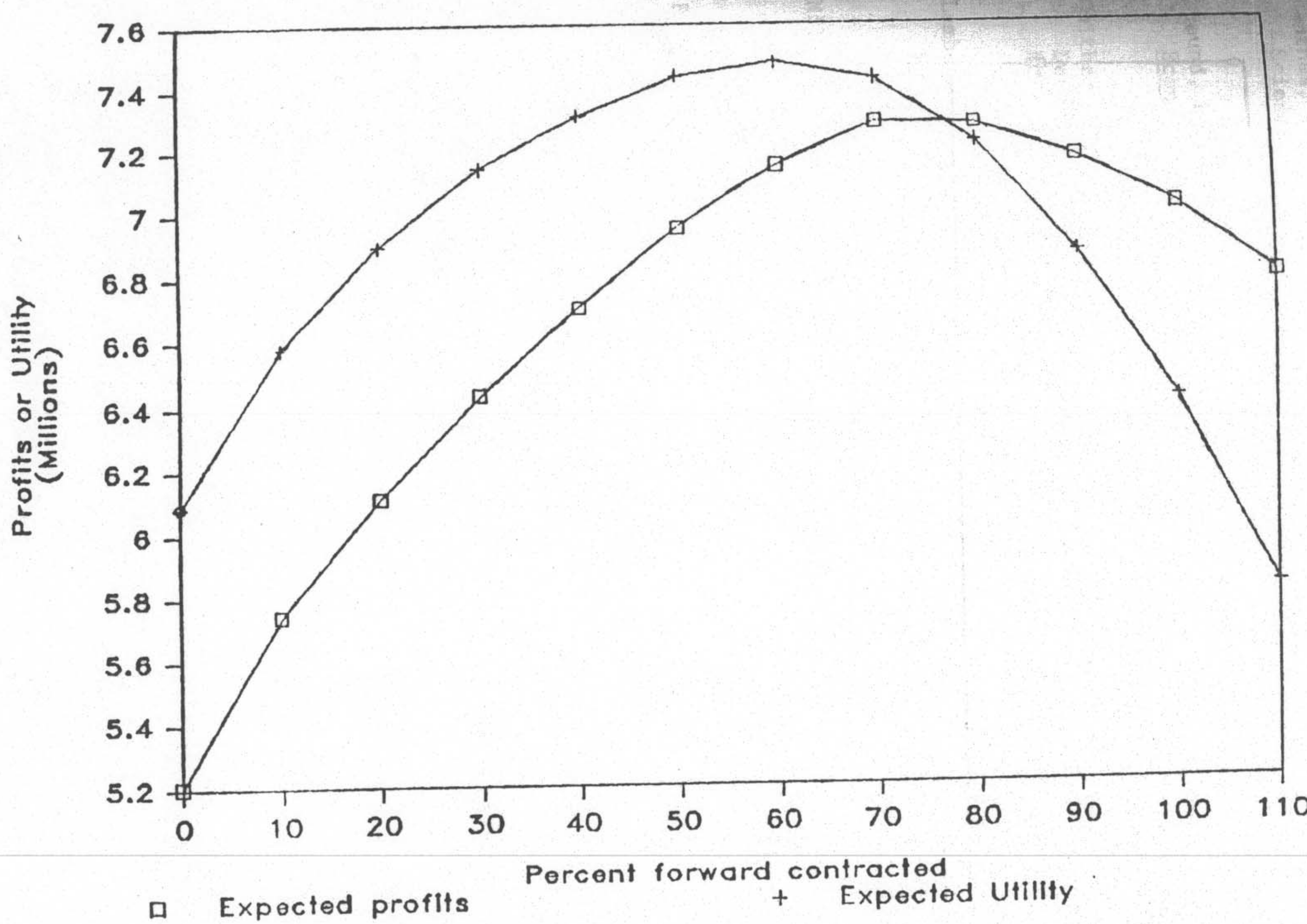

Figure 3. Utility of Forward Contracting.

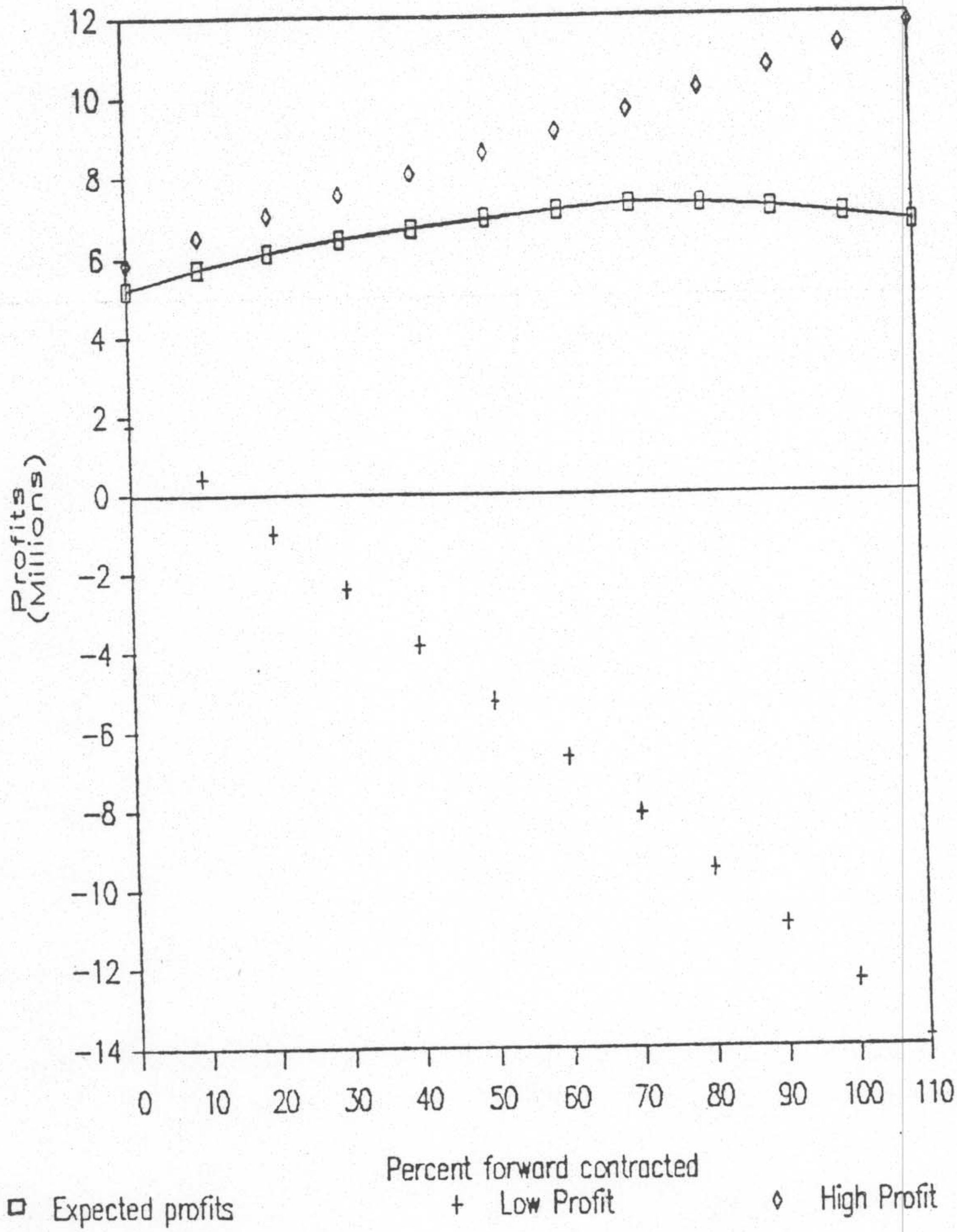

Figure 4. Profit Distributions.

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