USING SUBSIDIZED PUT OPTIONS TO REPLACE

THE FEDERAL PRICE AND INCOME

SUPPORT PROGRAMS FOR CORN

by

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(ABSTRACT)

Congress has directed the Department of Agriculture to perform research and establish a pilot program to determine the feasibility of using regulated agricultural commodity options trading for the benefit of farmers to protect them from fluctuations in the value of their commodities.

The purpose of this study is to examine the prospects for using put options in place of current farm income support programs. It focuses on the feed corn program in its analysis.

It also examines available literature on the subject of using futures and options contracts to replace current farm programs.

The study uses the Black model for the pricing of options on futures contracts to estimate prices of options that would provide a level of income protection similar to that afforded by the current income support program for corn farmers. It goes on to estimate the fair value of the
implicit put options granted by the Federal government for the 1982 - 1989 crops of corn and compares those values to actual program costs.

The results suggest the possibility that program costs are higher than they need be because government price and income guarantees are provided at a cost in excess of the fair market values of the current program's implicit options and that transfer of some or all of the risk-bearing role to the private sector would result in reduced government costs.
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# TABLE OF CONTENTS

Chapter I. Introduction ........................................... 1

Chapter II. The Federal Corn Program .......................... 5

Chapter III. Some Perspectives in the Literature .......... 12

Chapter IV. Method for Calculation of
Theoretical Minimum Put Values .............................. 20

Chapter V. Estimating the Cost of Using an Explicit
Subsidized Put Option Program to Replace the Current
Corn Producer Price and Income Support Programs .... 27

Chapter VI. Program Structure Considerations .............. 43

Chapter VII. Conclusions ......................................... 47

Bibliography ......................................................... 49

Vita ................................................................. 51
Chapter I. Introduction

Congress has directed the Department of Agriculture to perform research and establish a pilot program to determine the feasibility of using regulated agricultural commodity options trading for the benefit of producers of agricultural products to protect them from fluctuations in the value of the commodities they produce. The pilot program is to be operated so as to ascertain whether producers will accept and fully utilize this method of price protection if information is provided to the producers concerning its proper use and to determine the effect widespread adoption of such a futures options trading program would have on commodity prices. The program is to include the use of such options trading by farmers for crops of corn, wheat, and soybeans over the coming five crop years\(^1\).

The purpose of this study is to examine the prospects for using put options in place of current farm income support programs. It will focus on the feed corn program and will attempt first to describe the current program in terms of the implicit put options it represents. The study will demonstrate the calculation of minimum values for puts

equivalent to the options granted under the current program through the use of the Black formula for the determination of prices for options on futures contracts. Using data for the 1982 through 1989 crop years, option values will be calculated and comparisons will be made between the costs of the implicit options program represented by government activities in those crop years and the costs of purchasing options designed to provide equivalent income guarantees.

In general, under the current program two forms of protection are afforded to farmers who choose to participate. The price support program guarantees that the farmer will receive a minimum price for all of a crop produced on program acreage. At harvest the farmer is offered a loan at the support price rate. If the market price is not attractive in comparison to the price support rate, the farmer has the option of forfeiting the crop to the government which then releases the farmer from obligation to repay the loan. The price support feature tends to set a price floor in the market for corn.

The second feature of the program provides the farmer with direct payments equal to the difference between the higher of the price support or the market price and a "target price" (set higher than the support price). Unlike the price support aspect of the program -- under which
payments are based on actual production -- these "deficiency payments" are made based on historical production yields.

The law which directs the operation of a futures options pilot program requires that the options used have strike prices equivalent to the price support rate and to the target price rate.

Chapter II contains a more detailed description of the Federal program of price and income support for feed corn producers and of the government-granted put options implicit in the program.

Chapter III reviews several research papers related to the topic of using futures and options contracts to replace current farm programs.

Chapter IV contains a description of the method Dr. Fischer Black developed for estimating the value of a call option on a futures contract and how that method can be modified to determine put values through the use of the put-call parity price relationship.

Chapter V uses the methodology described in Chapter IV to estimate the minimum values of explicit put options that, if given to individual corn farmers in place of the current program's guarantees, would duplicate the income expectations of the farmer. It then compares actual Government program costs incurred in the operation of the
corn program to the estimated fair value of the implicit options embedded in that program.

Chapter VI raises some issues relating to the structure of a possible replacement program.

Finally, Chapter VII consists of some concluding remarks.
Chapter II. The Federal Corn Program

The Federal government encourages the production of major food, feed, and fiber crops through the provision of price support and income subsidy programs that reduce the uncertainty inherent in the management of a farming operation. Corn is the nation's most valuable field crop with annual farm receipts from 1984 - 1988 averaging $15.75 billion. U. S. production accounted for 41.3% of world production of corn during that period.

Under the provisions of the Federal government's corn program, the farmer is made aware of the price and income support that will be made available prior to planting of the season's crop. In accepting the government support, the farmer agrees to idle a certain percentage of his or her farm. Through this set-aside mechanism, the government has some control over production and thereby over taxpayer exposure under the program. Government costs are highly variable and have ranged from -$934 million for the corn program in fiscal year 1984 to $9,758 million in fiscal year 1987 (a negative figure indicates that the government received more in loan repayments than it made in new loans and that it sold previously forfeited stocks to the market). In general, program cost variability is a function of the
market price for corn. When the market price is high program costs tend to be low and when market prices are low, program costs tend to be high. For example, in the 1984 marketing year the average market price for corn was $3.25 per bushel. In the 1987 marketing year the average price was $1.50 per bushel. Direct payments to farmers have ranged from $1,753 million for the 1984 crop to $7,737 million for the 1987 crop.

Under the price support program provisions, upon harvest any participant may pledge all or a portion of his or her crop to the government's Commodity Credit Corporation as collateral for a loan. The loan rate is an amount per bushel that, under current policy, is based on average market prices for corn in the years preceding the relevant crop year, subject to a statutory minimum. The term of the loan is nine months. If, during the term of the loan, the farmer does not consider market offers to be attractive, he or she may forfeit the corn to the Federal government and receive cancellation of the obligation to repay the loan. Because participation in the corn program is generally high (in normal years participants account for about 80% of planted acres), the corn loan rate is considered to operate as a floor under corn prices in the market. For the program participant, the loan rate always serves as a floor.
In option terminology, the buyer of a put contract receives the right to sell a commodity at an agreed upon price at an agreed time (or during a certain period). The seller has the obligation to purchase the commodity according to the terms of the contract should the buyer choose to exercise the option. The price support feature of the corn program is a put with a strike price equal to the loan rate where the farmer is in the role of the put buyer and the government can be thought of as the seller. The option is granted prior to planting for the crop during the sign-up period (usually in March). Government's provision of the put is conditioned on the producer's agreement to preserve in an idle state a percentage of his or her crop acreage base.

The put has both European and American aspects to it. Since the farmer can only exercise the option after harvesting the crop, the put is European in style from the sign-up period until the harvest (harvest date is September 1 for purposes of this paper). No matter how far the option may be in-the-money at any given time during that period, the option cannot be exercised to take advantage of that condition. Starting with the supposed September 1 harvest, the farmer may take the government's loan at any time up to May 31 of the next year. The loan reaches maturity on the
last business day of the ninth month after the month in which the disbursement is made. If market prices are unattractive at harvest, the option may be exercised or the loan taken.

The option at the loan rate strike price is in-the-money any time that price available from the marketplace is less than the support rate. If the option expires in-the-money, the rational producer will exercise the right to transfer title of the corn to the government in return for the loan rate plus nine months use of the money.

If, after taking the loan, the producer finds that the put is sufficiently out-of-the-money that the optimal move is to sell to the market, he or she must repay the loan with interest and forfeit the remaining time value (if any) of the put option.

One feature of this government provided put program that is superior from the farmer's hedging perspective to exchange-traded puts is that there is no risk to the farmer that unintended exposure will occur as a result of variation in production yield. Under the current price support program, the non-recourse loan is available to each producer on an acreage basis regardless of the yield from that acreage. A farmer who uses exchange-traded puts to establish a minimum price must prior to harvest make an
estimate of what his or her actual production will be. To the extent that the producer's actual yield varies from the estimate, the farmer finds that an unintended position has been established either in the cash commodity (if the yield is high) or in the options market (if yield is low). The provisions of the government program represent an uncertainty in the government's exposure in granting the option and represents a quantity option held by the producer. Other things being equal, higher anticipated yields will increase the value of the implicit option per acre at the time of program sign-up.

Estimation of the value of the put implicit in the price support program requires knowledge of the sign-up date for the program, a date for harvest, calculation of the term of the loan, the risk-free interest rate, the current forward (or futures contract) price for corn, and the volatility of corn prices.

To simplify and recognize normal patterns, we will simply pick a harvest date (September 1), treat the sign-up date as being March 1 of the planting year, and the value of the put can be related as follows:

\[ P_s = P_s(S, F, T, r, s) \]
where:

\[ P_s = \text{value of the price support put}; \]
\[ S = \text{price support loan rate}; \]
\[ F = \text{The forward price for corn}; \]
\[ T = \text{time until expiration of the option}; \]
\[ r = \text{the risk-free rate of return}; \]
\[ s = \text{volatility of corn prices}. \]

The put implicit in the government price support program differs from exchange-traded commodity options in that it is an option in a cash commodity as opposed to an option on a short futures contract position. In addition, the rights conferred under the option are not transferrable and in that respect are not directly comparable to exchange-traded options.

Under the target price income support provisions of the corn program the government makes direct payments to farmers who participate and comply with the requirements of participation which can also be thought to consist of implicit put option contracts. Payments are made according to the difference between average market prices in the first five months after harvest (or the price support loan rate if that is lower) and a so-called "target price." Payments are calculated for each farm by multiplying the difference
between the target price and the market price and by the farm's acreage and by a yield factor determined for each farm according to an average of past years' production. The payments made under this aspect of the program are referred to as deficiency payments. The target price is always higher than the price support loan rate. While this part of the program does not afford the farmer the opportunity to actually exercise an option by selling grain, it does allow him or her to know in advance what total income from production represented by historical yield will be.

The value of the put implicit in the income support program can be described as:

\[ P_{TP} = P_{TP}(TP, R, F, T, r, s) \]

where:

- \( P_{TP} \) is the value of the put;
- \( TP \) is the target price; and
- the other variables are those described above.
Chapter III. Some Perspectives in the Literature

Glauber and Miranda\textsuperscript{2} model a program of subsidies for farmer purchases of loan rate equivalent put options as a replacement for the government price support programs for soybeans and wheat as well as corn. The model assumes that the current deficiency payment income support provisions continue as they are now configured. The options in their model are purchased at harvest. The strike price (equivalent to the loan rate) would be announced at the time of planting. This suggests that the government would carry the risk associated with price changes from the announcement date until the harvest date. An important observation made by the authors is that replacement of the price support programs and consequent removal of the floor under market prices will necessarily cause an increase in the volatility of prices. As will be shown in this study and as Glauber and Miranda note, other things being equal, higher price volatility will result in a higher option premium. They caution directly that historic option price relationships cannot be used to estimate the costs of implementing a

subsidized put option program.

The simulation developed by Glauber and Miranda estimates the effects of the replacement program on producers, consumers, private grain inventory holders, and taxpayers for the years 1989 - 1998. The model estimated prices, demand, yields, production, and ending stocks for the three crops under a variety of assumptions for the price elasticity of demand.

The results of the simulation generally show that market prices are slightly lower under the subsidized put option program with prices received by farmers and farm income being about the same as would be the case under extension of the current program. Variability of corn and soybean prices was found to be significantly higher. The simulation showed government costs to be quite similar over the ten-year period under the put program to what they would be under the current price support program. While the authors found that government costs were slightly lower under the subsidized option program, the difference was small -- particularly in comparison to the size of the program.

Glauber and Miranda estimated the total welfare gain to be derived from a change to a subsidized option program (consumer surplus plus increases in net producer revenues)
to be $6 billion over the ten-year period with domestic consumers and producers receiving $4.3 billion of that gain.

Heifner and Wright\(^3\) conducted a study to assess the usefulness of commodity futures, options, and cash forward contracts to farmers. Their study also identified and evaluated new types of commodity programs to provide for greater reliance on forward markets for price and risk shifting and assessed the Federal budgetary implications of alternative programs, including effects on the level and variability of expenditures.

In their theoretical evaluation of programs that expand farmers' direct or indirect use of futures or options markets, Heifner and Wright concluded that such programs cannot lower government costs without lowering the level of price protection granted. Nevertheless, they suggest that the Federal government might be able to reduce the uncertainty of its budgetary exposure by subsidizing farmers' use of futures and options markets since all or a greater portion of government costs would be known prior to harvest outcomes.

Heifner and Wright also survey the types of subsidies

that could be made available under an alternative program. The government subsidies they list include payments to cover transaction costs of exchange trading, payments to cover the costs of option premiums, special loans at harvest to replace the current non-recourse loans, and payments at the end of the marketing year to compensate the farmer for any difference between realized gain and support levels.

In considering the possible alternatives, Heifner and Wright also examine the possible timing decisions that could be adopted for payments and transactions. In developing a program, a key decision would have to be made as to whether the term of price protection would be provided to cover the growing season as well as the marketing season. They claim that a futures-options program would have little effect if participants could qualify for subsidies and then immediately trade out of their positions. While the claim is not expanded upon, their view seems to be that legitimate program objectives other than simple income transfer would go unmet if farmers participating in the program were permitted to liquidate their positions immediately.

Heifner and Wright also consider the prospects for using futures and options to reduce budgetary uncertainty and analyze the possibility of the government's direct participation in futures and options markets to hedge its
risks. They find that uncertainty could be reduced under the assumption that government trading could be readily absorbed without its participation distorting market prices. They note that such an assumption should not be expected to hold.

Dr. Petzel\(^4\) considered the problem of agricultural price uncertainty and examined the function and utility of private market tools -- as well as of government programs -- in managing risk. Petzel noted that the implicit but often unstated goal of farm policy is to achieve an improved price risk distribution for the producer of the crop in question. In the case of corn, he shows that where price supports reduce the risk faced by the corn farmer, they present a consumer such as a livestock producer with a symmetric but undesirable change in distribution in the form of a floor under the price of a key input component.

Petzel cites findings in the literature which show that while a producer's use of futures markets will not eliminate risks associated with price uncertainty, they can transform the risk problem to one of basis risk, which is presumably

more manageable.\footnote{5}

Petzel examined the U. S. domestic sugar price support program and found that the intrinsic value of the rights it granted where the implicit options were deep in-the-money (at the time of his examination world prices for raw sugar were at 5 cents per pound whereas the government price support program at the time guaranteed the producer a price of 21 cents per pound) was not difficult to estimate. He observed that such deep-in-the-money puts carry little or no time value and that their market value is expected to be near to the intrinsic value. A put option's intrinsic value is said to be the greater of zero and the strike price minus the market price. The option's time value makes up the difference between the intrinsic value and the market value. In the sugar case considered by Petzel, the implicit option had a value of about 16 cents per pound.

To consider the more complicated cases of cotton, corn and soybeans, Petzel used the Black option pricing formula

\footnote{5 To the corn farmer using futures markets to hedge price risk, basis risk essentially involves the difference between the price quoted on the futures exchange and the price which the producer could actually receive for his or her output. This price difference is thought to follow fairly predictable seasonal patterns over time and is primarily a function of transportation costs, availability of storage space, exchange and interest rates, and location specific demand. Currently, prices received by Iowa corn farmers are 20 - 25 cents lower than the spot month price on the Chicago Board of Trade.}
to estimate the values of the puts implicit in the government programs for those crops. He made comparisons of government costs under an explicit put option program using different estimates of support rates by varying the strike prices in the analysis. While noting that his work was not the proper forum for discussion of value received by the government in operating farm programs, he considered that his findings contributed to the notion that price support program goals could be achieved at reduced costs with the adoption of an explicit put program.

Petzel makes useful observations about the sensitivity of option premiums to volatilities in the underlying commodities. He singles out the corn market to make the point that use of option markets to replace completely the government program would dwarf the current level of options trading. In the most recent year for which data is available, total corn put option volume on the Chicago Board of Trade was on approximately 4 billion bushels. Annual U.S. production is about 8 billion bushels.

Dr. Gardner\textsuperscript{6} likened the deficiency payment income support feature of farm programs as well as price support to

put options on agricultural futures contracts. He made the important observation that use of puts can leave a producer with a speculative -- rather than hedged -- position to the extent that actual production is above or below the quantity hedged through the options market prior to planting. This uncertainty exists in some of the current agricultural price support programs and would be present in a put program equivalent to the loan rate price support program. Since corn deficiency payments are based on historical production -- rather than actual production -- that aspect of the program is more like exchange-traded put options than is the price support provision and does not carry production performance-related income uncertainty to the extent it is found in the price support feature.
Chapter IV. Method for Calculation of
Theoretical Minimum Put Values

The Black option pricing formula for options on futures contracts estimates the minimum price of a "European" call option.⁷ A European option is one which may be exercised only at the time of expiration of the contract. It contrasts in the terminology with the "American" option which may be exercised at any time up to expiration. Options which are currently traded on United States grain futures exchanges are American options. The calculation of the value of the American option is more complicated than that for a European-style contract. Since it confers additional rights in comparison to the European option, the American option will have a higher value, other things being equal.

The rule which demonstrates parity between puts and calls written at the same time with identical strike prices and expirations allows the calculation of the minimum premium for a European put given the minimum call premium (calculated using the Black formula) and the risk-free interest rate.

Black (expanding on work in which he cooperated with Myron Scholes\textsuperscript{8} to develop a method of calculating the price of an option on a security) derived his formula by starting from the establishment of a riskless hedge consisting of a long position in an option to buy a commodity futures contract (a call) and a short position in the futures contract. The call and the futures contract have the same expiration date. The value of the option can be isolated by the adoption of the assumption that the value of the riskless hedge position -- by definition -- must grow at the risk-free rate. Black notes that since the value of a futures contract position is zero, the equity in the portfolio is simply the value of the option, and the change in the value of the hedged portfolio is equal to the difference between the change in the value of the call and the change in the futures price times the size of the futures position. Black writes this change as:

\[ \Delta w = w, \Delta x \]

where:

- \( w = w(x,t) \) is the value of the option;
- \( \Delta w \) is the change in the option's value;

is the derivative of the value of the option with respect to the futures price (commonly known as the "delta" of the option and here defining the size of the futures position required to fill out the riskless hedge);

\[ x = x(t, t^*) \] is the futures price;

\[ \Delta x \] is the change in the futures price;

\( t \) is the current date; and

\( t^* \) is the expiration date.

At expiration \( (t^*) \), the value of the option is intuitively simple to determine. It must be the greater of zero and the futures price minus the contractually agreed upon exercise price of the option. Any other value would lead to arbitrage opportunities. Given this constraint, Black derives the formula for the value of the option at time \( t \):

\[ w(x,t) = e^{r(t-t^*)}[xN(d_1) - cN(d_2)] \]

where:

\[ d_1 = \frac{\ln(x/c^*) + s^2/2(t^* - t)}{s\sqrt{(t^* - t)}} \] / and

\[ d_2 = \frac{\ln(x/c^*) - s^2/2(t^* - t)}{s\sqrt{(t^* - t)}} \]

The formula reflects the intuition that a higher futures price \( (x) \) has a positive effect on the value of the
call and a higher exercise price ($c^*$) has the opposite
effect. $N(d_1)$ and $N(d_2)$ are taken from the normal
distribution table where $d_1$ and $d_2$ are the $z$-values. As the
formulas show, $d_1$ and $d_2$ are dependent on the futures price,
the exercise price, the time to expiration, and of $s$, which
is the standard deviation of changes in the price of the
underlying commodity. $N(d_1)$ can be described as the
probability that, at expiration, the spot value of the
underlying commodity will be equal to the current price and
$N(d_2)$ the probability that the price will be equal to the
options exercise price ($c^*$).

The derivation of a minimum put price (European-style)
is accomplished through the use of the Black formula for the
price of a call and of the put-call parity relationship.
The method is described by Dr. Chance. This relationship
involves establishment of a riskless portfolio position
consisting of a long put, a short call, a long position in
the futures contract and a long position in risk-free bonds
in the amount of $(x - c^*)$. The value of such a position is
described by the equation:

$$ p - w + (x - c^*)(1+r)^{-T} = 0 $$

where:

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9 Don M. Chance, *An Introduction to Options and Futures*
p represents the value of the put;  

r represents the risk-free interest rate; and  

\[ T = (t^* - t)/365. \]

That a position in a futures contract has a zero balance explains the fact that it is not represented in the equation for the portfolio. For a put with \( c^* \) greater than \( x \) the bonds in the position would be sold or written rather than purchased.  

To find the minimum put price we solve for \( p \):

\[ p = w - (x - c^*)(1+r)^{-T} \]

Since a put can never have a negative value, the formula must be subject to the constraint:

\[ p \geq 0 \]

so that if:

\[ (x - c^*)(1+r)^{-T} > w \]

then:

\[ p = 0 \]

To demonstrate the effects of changes in the variables of the Black formula modified by the put-call parity relationship to estimate the put price, we write the equation in its expanded form:

\[ p = e^{-rT}xN(d_1) - e^{-rT}c^*N(d_2) - (x - c^*)(1 + r)^{-T} \]

The comparative statics are:

\[ \frac{\delta p}{\delta x} = e^{-rT}N(d_1) - (1+r)^{-T} < 0; \]
\[ \frac{\delta p}{\delta c} = -e^{-rt}N(d_2) + (1+r)^{-T} > 0 ; \]

\[ \frac{\delta p}{\delta r} = -Te^{-rt}N(d_1) + Tc^*e^{-rt}N(d_2) \]

\[ + T(x - c^*)(1+r)^{-T-1} < 0 ; \]

\[ \frac{\delta p}{\delta T} = -re^{-rt} \frac{\delta N(d_1)}{\delta d_1} \left(-\frac{1}{2}ln(x/c^*)T^{-3/2} + (\frac{1}{2})(\frac{s}{T}) \right) \]

\[ + re^{-rt}c^* \frac{\delta N(d_2)}{\delta d_2} \left(-\frac{1}{2}ln(x/c^*)T^{-3/2} + (\frac{1}{2})(\frac{s}{T}) \right) \]

\[ + T(x - c^*)(1+r)^{-T-1} \text{ where the sign is not determined; and} \]

\[ \frac{\delta p}{\delta s} = e^{-rt}x \left( \frac{1}{sT} \ln \frac{x}{c^*} + \frac{s}{2T} \right) \frac{\delta N(d_1)}{\delta d_1} \]

\[ - e^{-rt}c^* \left( \frac{1}{sT} \ln \frac{x}{c^*} + \frac{s}{2T} - \sqrt{T} \right) \frac{\delta N(d_2)}{\delta d_2} > 0 \]

The first two partial derivatives confirm the intuition that as the underlying or futures market price \( x \) rises, the value of the put falls and as the option exercise price \( c^* \) rises the value of the put also increases. Put prices are shown here to have a negative relationship with interest rates. As interest rates fall, the return to the seller of the put (who would invest the premium proceeds) also falls. To compensate for the increased cost of carrying price risk, the option seller demands a higher premium when interest rates decline.
The effect of a change in time to expiration \((T)\) on the value of a put depends on the degree to which the strike price is away-from-the-money. Deep in-the-money or out-of-the-money puts have little time value and are not very sensitive to changes in time to expiration. The sign of the derivative of near-the-money-options depends on the volatility and interest rate assumptions.

Finally, the price of a put is positively related to changes in the volatility \((s)\) of the price of the underlying commodity.

The Black formula modified to estimate put prices is intended to describe fair prices for puts given assumptions regarding inputs. Uncertainties with respect to future price movements, interest rates, and price volatilities have important implications for consideration of explicit option subsidization programs to replace the U. S. government's current price and income support programs.
Chapter V. Estimating the Cost of Using an Explicit Subsidized Put Option Program to Replace the Current Corn Producer Price and Income Support Programs

For purposes of examining a subsidized put option program to replace the existing feed corn farmer price and income support programs, this paper uses the Black model for the pricing of options on futures contracts to estimate prices of options that would provide a level of income protection similar to that afforded by the current program. Under the program implied here, on the March 1 preceding a crop's planting, the Federal government would take long positions in put options that have a strike price that is equivalent to the minimum price determined to be necessary to provide adequate income protection for the farmer over the growing and marketing year. Target price equivalent strike price options are used here to approximate the full benefit afforded by the price and income support programs and could arguably serve as replacement for the program elements described here.

For purposes of this study, put values are calculated assuming the options expire approximately 340 days after they are written. As noted previously, the options implicit in the corn price and income support program actually
represent protection that is available for a greater length of time. The shorter period used here was chosen because it represents the most distant amount of time for which exchange-traded futures contracts are available. Consequently, the put values calculated here are likely to underestimate somewhat the value of options that truly replicate the existing program.

Having adopted March 1 of a given crop year as the sign-up date, we find that the most distant corn contract trading on the Chicago Board of Trade on that date to be that which expires in May of the following year. The government's price support put option program can provide price protection and marketing flexibility for approximately nine months beyond that time. The Black formula in part is a function of the price today of a futures contract that expires when the option expires. One could conceivably estimate what the price for a nine-month more distant futures contract would be for inclusion in the formula but that is a topic for another paper. The results obtained on the basis of actual trading in futures contracts should serve to illustrate any potential an explicit put option program may have as a replacement for the current corn program.

The description above of the Federal program indicates
that, in fact, different options at different strike prices are implicitly offered. The price support program consisting of the government's non-recourse loans carries the lower of the two exercise prices with the income support element offering the higher strike price.

Given that the target price program seems to most directly represent the farmers' income goal held by the Federal government, this study examines the value of explicit puts with exercise prices representing target prices and expiration dates approximately 340 days after the program sign-up date. The accompanying table (Table 1) summarizes the results from using the Black model to estimate put values.

The values of the puts range from $.132 per bushel in 1982 to $1.189 per bushel in 1987. The market price on the sign up date for the 1982 crop for delivery in Chicago in May 1983 was $3.0275 per bushel. The target price -- or government income support rate -- for the 1982 crop was $2.70 per bushel. The low estimated price for the option is expected since the option given by the government to the farmer is out-of-the-money -- that is, its intrinsic value is zero. In contrast, the high estimated price for the 1987 crop option is explained by the fact that the actual price for the futures contract on the sign-up date is
substantially lower at $1.79 per bushel than the target price which is $3.03 per bushel for that year.

Also of note is the wide range of standard deviation values for the individual contracts. Each standard deviation value is based on approximately 310 observations of daily market closing prices. The observed standard deviation values for the eight contracts covering the 1982 through 1989 crops range from .098 (1987) to .287 (1988). The standard deviation values used here are historical estimates of volatility based on the actual performance of the underlying futures contract. For example, the standard deviation used to price the option for the 1982 crop is that for the daily change in closing prices for the contract which expires in May 1983.
TABLE 1

Inputs for Calculation and Minimum Corn Program Equivalent Option Prices Determined Using the Black Formula as Modified by the Put-Call Parity Relationship for the 1982 - 1989 Crop Years (Prices in Dollars per Bushel)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard deviation of price¹</td>
<td>0.2651</td>
<td>0.2347</td>
<td>0.1510</td>
<td>0.1671</td>
</tr>
<tr>
<td>Market price on sign-up date²</td>
<td>3.0275</td>
<td>2.940</td>
<td>2.9675</td>
<td>2.7125</td>
</tr>
<tr>
<td>Target price</td>
<td>2.70</td>
<td>2.86</td>
<td>3.03</td>
<td>3.03</td>
</tr>
<tr>
<td>Interest rate³</td>
<td>.1107</td>
<td>0.088</td>
<td>0.0992</td>
<td>0.0781</td>
</tr>
<tr>
<td>Min. call premium⁴</td>
<td>.4308</td>
<td>0.2787</td>
<td>0.1314</td>
<td>0.0621</td>
</tr>
<tr>
<td>Min. put premium⁴</td>
<td>0.1317</td>
<td>0.2047</td>
<td>0.1886</td>
<td>0.3583</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Standard deviation of price¹</td>
<td>0.2206</td>
<td>0.0984</td>
<td>0.2867</td>
<td>0.1437</td>
</tr>
<tr>
<td>Market price on sign-up date²</td>
<td>2.15</td>
<td>1.772</td>
<td>2.262</td>
<td>2.782</td>
</tr>
<tr>
<td>Target price</td>
<td>3.03</td>
<td>3.03</td>
<td>2.93</td>
<td>2.84</td>
</tr>
<tr>
<td>Interest rate³</td>
<td>.0608</td>
<td>.0632</td>
<td>.0713</td>
<td>.081</td>
</tr>
<tr>
<td>Min. call premium⁴</td>
<td>.0112</td>
<td>.0000</td>
<td>.0617</td>
<td>.1183</td>
</tr>
<tr>
<td>Min. put premium⁴</td>
<td>.8448</td>
<td>1.1890</td>
<td>.6885</td>
<td>.1722</td>
</tr>
</tbody>
</table>

¹ The standard deviation of daily changes in contract closing price (low end of range) for relevant contract month. The 1982 value is for the May 1983 contract, the 1983 value for May 1984, etc.
² Closing price for the relevant futures contract on 1st trading day after March 1
³ Average interest rate during the calendar on short term U. S. Treasury securities
⁴ Put and call premium values are calculated using a strike price equal to the corn program target price
Table 2 provides an estimate of what government corn program outlays might have been for the 1982 through 1989 crops were it able to purchase puts at target price strike prices for the minimum Black formula values calculated here. The estimates represent the minimum cost of using explicit options to replicate the income support features of the program. The Black formula put values are multiplied by the officially reported base acreage for the nation's corn crop for each year and by the reported yield per acre for that year. The figure for each year represents the minimum amount that the government would have had to pay to purchase puts for corn farmers in an amount sufficient to secure the income protection contained in that year's corn policy for all of the year's production. Table 2 also shows actual government costs for the corn program for that year and the totals for the eight years from 1982 through 1989. On a year to year basis, the cost of the explicit put option program is not directly comparable to the government's reported corn program costs. The put figures implicitly represent the government's costs -- and all of its costs -- of running the program in the year in question. Actual program costs, on the other hand, reflect government profit and loss outcomes from that crop year as well as from continuing operations related to prior crop years. The
eight year totals would seem to provide a more sound basis for comparison between the put program and the program that has been in place. Warning should be taken that there may be objectives of the current program (such as stabilization and management of stocks) that are not addressed by the explicit put program which cause even the longer term cost figures to be unsuitable for a strict comparison.

Nevertheless, the predominant purpose of the corn program is to provide price protection to the farmer. The results here suggest that the government's costs in operating the current program over an eight-year period exceeded by 39% the fair market value of the implicit puts embedded in the program's price and income support features.
### TABLE 2

Inputs for Calculation of the Costs of Using an Explicit Subsidized Put Option Program as a Replacement for the Current Federal Price and Income Support Program for Feed Corn and Comparison with Actual Costs for the 1982 - 1989 Crop Years

(Prices and Premiums in Dollars per Bushel)

<table>
<thead>
<tr>
<th></th>
<th>1982</th>
<th>1983</th>
<th>1984</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market price on sign-up date</td>
<td>3.0275</td>
<td>3.94</td>
<td>2.9675</td>
</tr>
<tr>
<td>Target price</td>
<td>2.700</td>
<td>2.860</td>
<td>3.030</td>
</tr>
<tr>
<td>Min. put premium</td>
<td>0.132</td>
<td>0.205</td>
<td>0.189</td>
</tr>
<tr>
<td>Avg. yield (bu./acre)</td>
<td>113.2</td>
<td>81.1</td>
<td>106.7</td>
</tr>
<tr>
<td>Base acres (mil.)</td>
<td>81.3</td>
<td>82.6</td>
<td>80.8</td>
</tr>
<tr>
<td>Total production (mil. bu.)</td>
<td>8,235</td>
<td>4,175</td>
<td>7,764</td>
</tr>
<tr>
<td>Actual program costs ($ mil.)</td>
<td>4,281</td>
<td>5,720</td>
<td>(934)</td>
</tr>
<tr>
<td>Explicit put program costs¹</td>
<td>1,212</td>
<td>1,371</td>
<td>1,626</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>1985</th>
<th>1986</th>
<th>1987</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market price on sign-up date</td>
<td>2.7125</td>
<td>2.15</td>
<td>1.772</td>
</tr>
<tr>
<td>Target price</td>
<td>3.030</td>
<td>3.030</td>
<td>3.030</td>
</tr>
<tr>
<td>Min. put premium</td>
<td>0.358</td>
<td>0.845</td>
<td>1.189</td>
</tr>
<tr>
<td>Avg. yield (bu./acre)</td>
<td>118</td>
<td>119.3</td>
<td>119.4</td>
</tr>
<tr>
<td>Base acres (mil.)</td>
<td>84.2</td>
<td>81.7</td>
<td>81.5</td>
</tr>
<tr>
<td>Total production (mil. bu.)</td>
<td>8,877</td>
<td>8,250</td>
<td>7,072</td>
</tr>
<tr>
<td>Actual program costs ($ mil.)</td>
<td>4,403</td>
<td>10,524</td>
<td>12,346</td>
</tr>
<tr>
<td>Explicit put program costs¹</td>
<td>3,560</td>
<td>8,234</td>
<td>11,570</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>1988</th>
<th>1989</th>
<th>TOTAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Market price on sign-up date</td>
<td>2.262</td>
<td>2.782</td>
<td></td>
</tr>
<tr>
<td>Target price</td>
<td>2.930</td>
<td>2.840</td>
<td></td>
</tr>
<tr>
<td>Min. put premium</td>
<td>0.689</td>
<td>0.172</td>
<td></td>
</tr>
<tr>
<td>Avg. yield (bu./acre)</td>
<td>84.6</td>
<td>116.2</td>
<td>107.3</td>
</tr>
<tr>
<td>Base acres (mil.)</td>
<td>82.9</td>
<td>82.7</td>
<td></td>
</tr>
<tr>
<td>Total production (mil. bu.)</td>
<td>4,921</td>
<td>7,527</td>
<td>56,821</td>
</tr>
<tr>
<td>Actual program costs ($ mil.)</td>
<td>8,227</td>
<td>2,863</td>
<td>47,430</td>
</tr>
<tr>
<td>Explicit put program costs¹</td>
<td>4,829</td>
<td>1,655</td>
<td>34,058</td>
</tr>
</tbody>
</table>

¹ Base acres x Avg. yield x Min. put premium
A regression analysis of the calculated Black option prices for the eight crop years confirms that they are quite sensitive to changes in underlying market prices. The ordinary least squares regression with the estimated minimum put option value calculation as the dependent variable and with the futures price on the sign-up date, the target price, the standard deviation, and the interest rate as explanatory variables yields results summarized in Table 3:

**TABLE 3**

Results of Ordinary Least Squares Estimation of the Coefficients of the Standard Deviation, the Price of the Underlying Commodity on the Sign-Up Date, the Interest Rate, and the Target Price with the Estimated Option Price as the Dependent Variable

<table>
<thead>
<tr>
<th>Regression Output:</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>1.286</td>
</tr>
<tr>
<td>Std Err of Y Est</td>
<td>0.079</td>
</tr>
<tr>
<td>R Squared</td>
<td>0.982</td>
</tr>
<tr>
<td>No. of Observations</td>
<td>8</td>
</tr>
<tr>
<td>Degrees of Freedom</td>
<td>3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Underlying</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>St. Dev.</td>
<td>Futures Price</td>
</tr>
<tr>
<td>Coefficients</td>
<td>0.414</td>
</tr>
<tr>
<td>Std Err of Coef.</td>
<td>0.539</td>
</tr>
</tbody>
</table>

As well as being sensitive to the movements of actual futures market prices the Black formula option prices are
sensitive to changes in market estimation of the volatility of prices (measured here as the standard deviation of daily changes). The regression results demonstrate this and confirm the expectations from the formula.

A more graphic demonstration can be seen by altering the standard deviation used in specific calculations. Table 4 gives examples demonstrating the sensitivity of the Black option for the 1985 crop year to changes in the standard deviation, using standard deviation values within the range of those observed in different one year periods over the eight years.

TABLE 4

<table>
<thead>
<tr>
<th></th>
<th>.10</th>
<th>.15</th>
<th>.167*</th>
<th>.20</th>
<th>.25</th>
<th>.30</th>
</tr>
</thead>
<tbody>
<tr>
<td>Put price</td>
<td>.271</td>
<td>.309</td>
<td>.324</td>
<td>.353</td>
<td>.400</td>
<td>.448</td>
</tr>
</tbody>
</table>

* Observed value

These calculations suggest that the option values (and as a result possible government costs) are subject to significant uncertainty connected with market estimates of volatility. For 1985, costs of an implicit option program could have varied by as much as 65% depending on the
market's anticipation of price volatility from the range observed over the eight-year period.

It may be that using the observed volatility measures lagged by one year would be a better method for determining the option value. Lagged standard deviation would result in the calculation of option values embracing recent volatility and does not require the assumption that on a given trading day the market will correctly anticipate the market volatility that will occur over the life of the options contract.

The results of the estimates of put values using standard deviations lagged by one year for the period 1983 - 1989 (i.e., the 1983 estimate of the put option that would provide the farm program's income protection is calculated using the standard deviation of prices observed during 1982 and early 1983) are shown in Table 5. The lowest value observed was $0.236 (1983) and the highest value observed was $1.19 (1987). Estimates of government costs based on the calculated option values range from $1,578 million (1983) to $11,578 million (1987) (Table 6).

Another measure of volatility that can be employed in estimating the put values is that derived from observations of exchange-traded put options. Since February 1985, trading in options on corn futures contracts has been
transacted on the Chicago Board of Trade. Because the terms of trading in each option expiration month is shorter even than the term of trading in corn futures contracts, the prices for options have not been used to determine the feasibility and costs of an explicit put option program to replace the current Federal program. Observed option prices in these markets can, however, permit the derivation of the market's estimate of the anticipated volatility (the so-called "implied volatility").

Implied volatility is calculated by treating the observed put price as the solution to the option pricing formula and considering the standard deviation to be the formula's unknown value. Determining that value reveals the market's expectation for the standard deviation of the price of corn between the trading date and the option's expiration. Since the option formula cannot be solved for the standard deviation, values are substituted in the formula until the one is found which yields an option price near the observed price.

Implied volatilities here are calculated based on put option prices observed on the first trading day of March (1985 - 1989) for the option that expires in September of that year. Strike prices are selected to be those which are closest to being at-the-money on that date (e.g., on March
1, 1985, the September futures contract closed at $2.675 per bushel. The put price selected was for that with a strike price of $2.70 per bushel. The implied volatilities calculated here range from .127 (1985) to .301 (1989) and average .212. The average standard deviation of daily price changes on the eight futures contract used in this study is .196. Table 7 shows the data used for the calculation of the implied volatility figures.


Table 5 shows the estimated option values calculated using the volatilities observed during the period following the first trading day, those volatilities lagged by one year, and the implied volatilities calculated with the put option formula and observed option values. A comparison of these results seems to suggest that the market is more likely to accept recently observed price changes as the basis for its estimate of volatility in the upcoming period, although this is not the case in each instance.
### TABLE 5

Estimated Put Values (in Dollars per bushel) Under Ex Ante Knowledge of Volatility, Implied Volatilities and Volatilities Lagged by One Year

<table>
<thead>
<tr>
<th></th>
<th>Ex Ante Knowledge of Volatility</th>
<th>Implied Volatility</th>
<th>Volatility Lagged by one year</th>
</tr>
</thead>
<tbody>
<tr>
<td>1982</td>
<td>0.132</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>0.205</td>
<td>0.236</td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>0.189</td>
<td>0.276</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>0.358</td>
<td>0.346</td>
<td>0.328</td>
</tr>
<tr>
<td>1986</td>
<td>0.845</td>
<td>0.836</td>
<td>0.836</td>
</tr>
<tr>
<td>1987</td>
<td>1.189</td>
<td>1.190</td>
<td>1.191</td>
</tr>
<tr>
<td>1988</td>
<td>0.689</td>
<td>0.627</td>
<td>0.652</td>
</tr>
<tr>
<td>1989</td>
<td>0.172</td>
<td>0.314</td>
<td>0.328</td>
</tr>
</tbody>
</table>

Table 6 shows a comparison of actual corn program costs and costs of operating a subsidized put option program using the minimum values under the three different volatility measures.
TABLE 6
Actual Program Costs Compared to Estimated Costs Using Subsidized Puts Based on Ex Ante Knowledge of Volatility, Implied Volatilities and Volatilities Lagged by One Year

<table>
<thead>
<tr>
<th></th>
<th>Actual</th>
<th>Estimated</th>
<th>Estimated</th>
<th>Estimated</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Program</td>
<td>Put</td>
<td>Put</td>
<td>Put</td>
</tr>
<tr>
<td>Costs</td>
<td>costs</td>
<td>costs</td>
<td>costs</td>
<td>costs</td>
</tr>
<tr>
<td>Vol. ex</td>
<td>(Lagged</td>
<td>(Imp.</td>
<td>Vol.</td>
<td>Vol.)</td>
</tr>
<tr>
<td>ante)</td>
<td>vol.)</td>
<td>vol.)</td>
<td>vol.)</td>
<td></td>
</tr>
<tr>
<td>1982</td>
<td>4,281</td>
<td>1,212</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1983</td>
<td>5,720</td>
<td>1,371</td>
<td>1,578</td>
<td></td>
</tr>
<tr>
<td>1984</td>
<td>(934)</td>
<td>1,626</td>
<td>2,376</td>
<td></td>
</tr>
<tr>
<td>1985</td>
<td>4,403</td>
<td>3,560</td>
<td>3,435</td>
<td>3,263</td>
</tr>
<tr>
<td>1986</td>
<td>10,524</td>
<td>8,234</td>
<td>8,146</td>
<td>8,148</td>
</tr>
<tr>
<td>1987</td>
<td>12,346</td>
<td>11,570</td>
<td>11,578</td>
<td>11,592</td>
</tr>
<tr>
<td>1988</td>
<td>8,227</td>
<td>4,829</td>
<td>4,398</td>
<td>4,571</td>
</tr>
<tr>
<td>1989</td>
<td>2,863</td>
<td>1,655</td>
<td>3,015</td>
<td>3,151</td>
</tr>
<tr>
<td>TOTALS</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>82 - 89</td>
<td>47,430</td>
<td>34,057</td>
<td></td>
<td></td>
</tr>
<tr>
<td>83 - 89</td>
<td>43,149</td>
<td>32,845</td>
<td>34,526</td>
<td></td>
</tr>
<tr>
<td>85 - 89</td>
<td>38,363</td>
<td>29,848</td>
<td>30,572</td>
<td>30,725</td>
</tr>
</tbody>
</table>

Under each assumption for volatility, the earlier result is confirmed. Actual program costs substantially exceed the fair market value of the implicit costs embedded in the program. Under lagged volatility and implied volatility estimates, costs exceed the put values by 25% over the relevant time periods.
<table>
<thead>
<tr>
<th>Year</th>
<th>Sept. futures</th>
<th>At-the-money prem.</th>
<th>Put strike</th>
<th>(cts./ bu.)</th>
<th>Put implied volatility</th>
</tr>
</thead>
<tbody>
<tr>
<td>1985</td>
<td>$2.675</td>
<td>$2.700</td>
<td>0.1025</td>
<td>0.127</td>
<td></td>
</tr>
<tr>
<td>1986</td>
<td>$2.098</td>
<td>$2.100</td>
<td>0.0950</td>
<td>0.169</td>
<td></td>
</tr>
<tr>
<td>1987</td>
<td>$1.612</td>
<td>$1.600</td>
<td>0.1000</td>
<td>0.249</td>
<td></td>
</tr>
<tr>
<td>1988</td>
<td>$2.154</td>
<td>$2.200</td>
<td>0.1475</td>
<td>0.215</td>
<td></td>
</tr>
<tr>
<td>1989</td>
<td>$2.744</td>
<td>$2.700</td>
<td>0.1950</td>
<td>0.301</td>
<td></td>
</tr>
<tr>
<td>1990</td>
<td>$2.540</td>
<td>$2.500</td>
<td>0.1125</td>
<td>0.197</td>
<td></td>
</tr>
</tbody>
</table>
Chapter VI. Program Structure Considerations

In structuring an explicit option program to replace the current program, a determination would first have to be made as to whether exchange-traded option contracts are to be used or whether some new and separate system for the purchase of puts is to be developed. Before futures and options exchanges could be persuaded to alter the terms of their traded contracts, a number of questions regarding the replacement program's structure and impact would have to be answered. For example, if the replacement program required farmers who are granted subsidized options to hold those options to expiration and the duration was calculated to duplicate protection now available from the sign-up date, the exchanges and options market-makers may find that longer duration options would not be of sufficient liquidity to justify their trading in the first place.

In the face of such an impediment, the government could choose to continue to carry price risk for a period, say, for the growing season, and make the subsidized options available to farmers for a shorter duration during the marketing (post-harvest) season. For that matter, the government could choose any mix of timing for carrying price risk and passing it off through the purchase of exchange-
traded put options. The question would still have to be answered regarding when, if ever, the farmer could sell the subsidized put.

Some policy-makers may feel that program objectives dictate that the farmer-recipient of a subsidized option should not be allowed to sell the option. For example, if the option is granted on the sign-up date and the farmer sells it immediately to pocket its market value, he or she may no longer have sufficient incentives to make production and management decisions in a manner that is consistent with the government's program objectives.

A different approach to establishing an explicit subsidized put option program would forgo the use of commodity exchange contracts in favor of the establishment of a government option market. Under such a program, the government would solicit bids after the sign-up date from private sector option sellers. The solicitation would specify the number of bushels to be covered, the strike price, and the duration of the option. Once the options are purchased and transferred to farmers, the government could take on a role similar to that of an exchange clearinghouse. Farmers who participate could choose to exercise the option by delivering their crop to the government which would then assign the exercise obligation to one or more of the option
sellers. Such a program would achieve the objective of shifting price risk from the taxpayers to private sector participants who are willing to carry it. The logistical problems involved in setting up such a program — particularly in working out the delivery arrangements — would have costly solutions. A possible solution to the delivery problem would be to allow for cash settlement of an exercised option in place of delivery of the physical commodity. Under a cash settlement system, if a farmer chooses to exercise the option when the market price is below the option's exercise price, the government would assign the exercise obligation to an option seller who would make a cash payment equal to the difference between the market price and the exercise price for transfer to the farmer. Under such a program, an important problem that does not have a simple solution is that of choosing a market price quotation to be used as the basis for cash settlement payments.

Whether or not physical delivery was required under the option program, a government-administered option market would come with a bonding problem. Some method would have to be devised that would ensure that option sellers meet their contractual obligations when market prices are low and exercise is probable. The problem could be addressed
through the imposition of capital requirements with careful
monitoring of maintenance; through the requirement that
option sellers post performance bonds in cash -- such as the
margin requirements currently in place in equity options
markets; or through other sanctions such as the threat of
prohibition from future participation.

The bonding problem in any event would be costly to
solve and has implications for the ability of the government
to make economically efficient trades as well as secure
ones. These costs must be considered in the course of the
development of an explicit option program that would serve
as an effective replacement for agricultural income support
programs.
Chapter VII. Conclusions

The preceding discussion and estimates suggest the possibility that taxpayers could achieve the objectives of farm income protection at reduced cost through the use of a subsidized put option program. Such a conclusion can only be drawn with confidence if one assumes that a system can be devised that achieves those objectives efficiently. Reference is made to the fact that currently, organized futures exchanges do not trade contracts in futures or options with sufficient duration to allow assumptions of the price risks currently carried by the government from the sign-up date. Presumably, considerable start-up costs would have to be incurred before the system could duplicate the implicit options embedded in the current program.

Heifner and Wright concluded that government cost savings could not theoretically be achieved at current support levels through a subsidized put option. If the foundation of their argument is that the government can bear the risks embedded in the current program as efficiently as the private sector, then there is no reason to believe that their conclusion is incorrect. This study suggests the possibility that program costs are higher than they need be because government price and income guarantees are provided

47
at a cost in excess of the fair market values of the current program's implicit options and that transfer of some or all of the risk-bearing role to the private sector would result in reduced government costs.
Bibliography


Vita

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