DEVELOPMENT OF VARIABLE ETHANOL SUBSIDY AND COMPARISON WITH THE FIXED SUBSIDY

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Staff Paper # 06-16

November 2006

Agricultural Economics Department

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Abstract

The federal government currently subsidizes ethanol with a fixed payment of $.51/gallon of ethanol blended with gasoline. Ethanol profitability is closely linked to the prices of corn and ethanol. The purpose of this paper was to develop a variable subsidy based on corn and ethanol prices and then to compare that variable subsidy with the fixed subsidy.

This analysis proceeded in several distinct steps:

- First, we estimated ethanol profitability over a wide range of ethanol, corn, and distillers grains prices.
- This data was used in a regression analysis to estimate the ethanol profitability from the set of corn and ethanol prices. The regression coefficients became the basis for the variable subsidy.
- A version of the subsidy that used gasoline prices instead of ethanol prices was also developed.
- Administratively, it would be burdensome to have a subsidy that changed every month, so we implemented both variable subsidies using quarterly data.
- We then compared the average annual government cost and monthly private profitability using historical data and assuming the variable subsidy and the $0.51 fixed subsidy was applied.

When using historic gasoline and corn prices from the last ten years, the variable rate subsidy cost the government nearly 40% less than the flat rate subsidy. Profit received by producers on average is a little less; however, producer's risk is lower with the variable subsidy than the flat rate subsidy.

Keywords: Ethanol, variable subsidy, energy policy, ethanol economics

JEL codes: Q48, Q42, Q28

Table of Contents

List of Figures

List of Tables

History of Ethanol Legislation

With higher petroleum prices, alternative fuel sources have begun to be investigated not only in the United States but world-wide. Currently, one of the leading fuel alternatives for gasoline is ethanol. Ethanol is a renewable fuel, meaning it is derived from a biomass that can be reproduced. In the United States ethanol is produced primarily from corn. Currently, ethanol is primarily used as a gasoline additive in which it adds octane and oxygen content to gasoline. Ethanol is used as an oxygen additive because it contains more oxygen than gasoline and burns cleaner, which is beneficial to the environment. Much of the gasoline in the United States currently is either a 10% or 15% ethanol blend (RFA 2005).

Webster's Dictionary defines ethanol as a colorless, volatile flammable liquid that is the intoxicating agent in liquors and is also used as a solvent. It is also referred to as ethyl alcohol or grain alcohol. Ethanol is used in three main applications: fuel, beverage, and industrial. Of these, fuel ethanol accounts for 73% of all ethanol usage with beverage use accounting for 17% and industrial for 10% (RFA 2005).

The ethanol industry is a relatively young industry that is continuing to grow and expand. Ethanol has been known since almost the beginning of time as the active alcohol ingredient in alcoholic beverages. However, ethanol, as a renewable oxygen additive in gasoline, is a much younger idea. Federal legislation has played a major role in the development of the ethanol fuel industry in the U.S. since the late 1970's. Table 1 provides a history of ethanol legislation.

Currently in the United States, ethanol is a subsidized commodity causing it to gain much attention and controversy. The ethanol subsidy began with the *Energy Tax Act* of 1978, which provided an exemption of the federal excise tax on gasoline (North Dakota 2005). These tax exemptions continued through the following decades. Currently, every gallon of ethanol blended with gasoline receives a 51 cent per gallon flat rate subsidy as a tax credit for the ethanol blender (no longer an excise tax exemption), which was established with the 2004 *Jobs Creation Act* (Energy 2005). The Renewable Fuels Standard (RFS) was passed in 2005 which requires 4 billion gallons of renewable fuels to be produced in 2006 (RFA 2005). If all of the renewable fuel produced were ethanol, the subsidy cost for 2006 would be over $2 billion.

Table 1: History of Ethanol Legislation

Year	Legislation
1978	Energy Tax Act of 1978
1980	The Crude Oil Windfall Profit Tax Act and The Energy Security Act
1982	The Surface Transportation Assistance Act
1984	Tax exemption in The Surface Transportation Assistance Act was increased
1988	Alternative Motor Fuels Act
1990	Congress required oxygen additives to be used in gasoline
1992	The Energy Policy Act
1995	Congress extended tax exemption to include all 10% ethanol-gasoline blends
1998	Congress extended the ethanol subsidy until 2007
1999	States began banning MTBE as an oxygen additive
2000	EPA recommended that all states phase out MTBE
2004	Jobs Creation Act
2005	Energy Policy Act of 2005

The Ethanol Industry

The ethanol industry has seen much change, especially in the past few decades. Some of the areas that have changed most are demand, usage, and government support. One area that has not seen much change over the past few decades is the way ethanol is produced. Ethanol is produced primarily through two methods: dry milling and wet milling. The basic steps of producing ethanol are very simple and similar between the two methods with the main difference being the preliminary treatment of the grain. The ending ethanol product is identical for both of these processes. In 2004, 75% of ethanol produced was from dry milling while 25% was from wet milling (RFA 2005).

While ethanol production techniques have remained somewhat unchanged over the last few decades, ethanol production has grown rapidly since production started. In 1980, ethanol production was about 200,000 gallons. In 2005, 4.0 billion gallons were produced (RFA 2006). This is an increase of 20,000% throughout these 25 years. The evolution of ethanol production is shown in Figure 1. Ethanol production has increased steadily throughout this time, but with a drop in 1996 when corn prices approached $5/Bu.

Some individual states also support ethanol production through incentive programs. Many of these states are located throughout the Midwest where corn is abundant. There are six main incentive programs provided by states:

- Producer incentive payments
- Retailer incentives for all ethanol blends
- State renewable fuel standards
- MTBE bans
- Ethanol labels on fuel pumps
- State fleets required to purchase vehicles that run on ethanol blends (primarily 85% ethanol-gasoline blends known as E85).

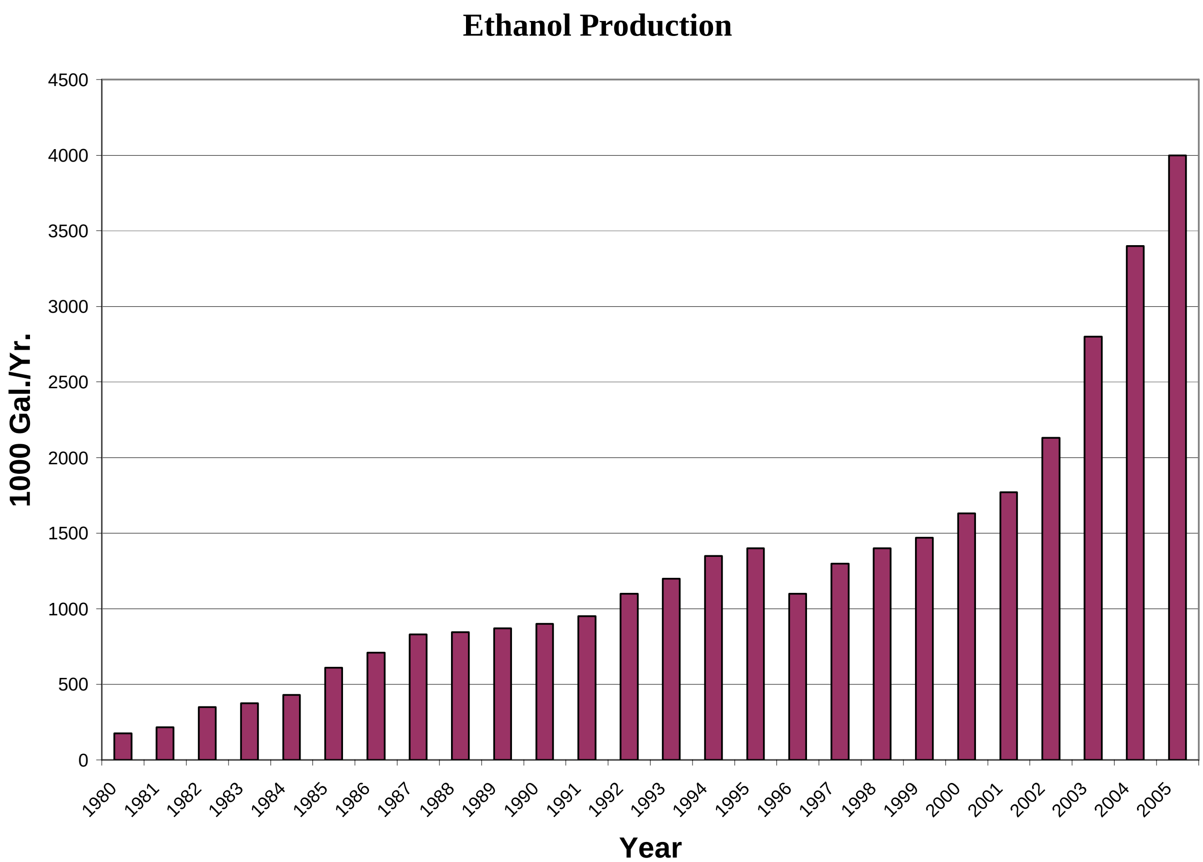

Figure 1: Ethanol Production History **(RFA 2006)**

This analysis will look more deeply at the ethanol industry and specifically at the ethanol subsidy provided by the federal government. The current 51 cent flat rate subsidy is very costly for the federal government, and with the Renewable Fuels Standard, the cost will likely increase in the future. The current subsidy also may not reduce risk assumed by producers in extreme price situations. This research provides an analysis of the advantages and disadvantages of having a varying subsidy rate that changes as input costs and ethanol prices fluctuate rather than the currently used flat rate subsidy.

Analysis of a Variable Ethanol Subsidy

This section describes the steps taken to create and analyze a variable rate subsidy for ethanol. A variable rate subsidy could be useful because the current flat rate subsidy may not be as efficient in reducing risk as is possible with a variable rate subsidy. The analysis encompasses the following steps:

- Estimation of ethanol profitability under a wide range of corn and ethanol prices
- Developing a relationship between corn and ethanol prices and profitability using a regression analysis and use the regression equation to formulate a monthly varying subsidy payment
- Developing a relationship between ethanol and gasoline prices using a regression analysis to create a varying subsidy payment based on the corn and gasoline markets
- Developing a quarterly varying subsidy payment that may be more feasible for the government to administer
- Use historical prices from the last ten years to calculate private profitability and government cost for both the variable and fixed subsidies

Profitability Estimation

The first step in creating an ethanol subsidy is to estimate the profitability of a current ethanol facility. A model has been created illustrating the functions of an average ethanol plant in the United States by Douglas Tiffany and Vernon Eidman of the University of Minnesota. In this model all of the input and output prices are used to create values that closely represent real life production costs and revenues.

This model was used to estimate profitability of ethanol production, and the profitability amounts from this model were used in other models to create a variable rate subsidy. In ethanol production, the main input is corn and the main output is ethanol. There are other inputs that go into production, but corn by far is the most important and has the largest effect on the cost of production. Similarly, a majority of sales come from the sale of ethanol, but other by-products are sold. Distiller's dried grain with solubles (DDGS) is the most common by-product sold from ethanol plants, and a significant amount of revenue is generated from its sales. Because corn price and ethanol price are the two main variables, they will be altered to create different life like situations. Ranges of corn and ethanol prices will be used to determine profitability at these different prices. The corn prices also will be used to predict DDGS prices, which also will be varied in the spreadsheet model.

Before these price ranges could be used in the model, other input and output values were updated to create a more realistic and up-to-date model. Other than the price for ethanol, corn, and DDGS, the values shown in Figure 2 were the ones used in the analysis. Figure 2 is a snapshot of the model.

The nameplate capacity factor is adjusted to .95 which assumes that this plant is operated 95% of its time producing ethanol. The interest rate is adjusted to .08 which is the current rate that most ethanol plants are likely to see. The anhydrous ethanol extracted was changed to 2.6 [1] which is a realistic number for modern production. The DDGS price was estimated using the following equation:

$$\text{DDGS Price} = -9.205 + 1.037(PC) + .135(SBM)$$
$$\text{T-Stat: } (-2.2) \quad (10.9) \quad (4.6)$$
$$\text{Adjusted } R^2 = 0.73$$

where PC is the price of corn per ton and SBM is the price of soybean meal per ton. The most recent price for soybean meal is $223.42 per ton, which was used as a constant in this equation.[1] The corn price in this equation was set to change as the corn price for the entire model changed. This allows for the DDGS price to change with the input price of corn providing us a varying DDGS price.

After adjusting these figures, a range of ethanol and corn prices had to be created. Looking at historic prices to create the ranges, the corn price range would be $1.50 to $4.00 changing in $.25 increments. The ethanol price range would be from $.80 to $1.60 changing in $.10 increments. Every possible combination of these prices was entered, and the profit outcomes from each combination were transferred to a table. The model is of a plant that has the capacity to produce 40,000,000 gallons of ethanol if it were 100% efficient. The profit outcome is measured from 38,000,000 gallons (95% efficiency) so this number had to be divided by 38,000,000 to get a measurement of profit per gallon, which is much more useful. Table 2 provides profit amounts for each combination of corn and ethanol prices.

Table 2 also provides a good illustration of the need of an ethanol subsidy for ethanol production to be profitable. There are very few combinations of ethanol and corn prices for which ethanol is profitable without help from a subsidy. This also shows that profits from an ethanol plant are constantly changing due to the changing nature of corn and ethanol prices. This emphasizes the possible utility for a variable rate subsidy that is based on changes within both of these markets. A flat rate subsidy is only completely efficient at a few of these price combinations.

[1] This estimation was done by Rhys Dale, a graduate student at Purdue University, also working on dry-milling ethanol issues. DDGS data came from the USDA, and corn and soybean meal data was from Bloomberg's electronic database.

1	B	C	D	E	F	G	H	I
2	**Ethanol Dry Mill Spreadsheet**		**by Douglas G. Tiffany, University of Minnesota**					
3	7/23/2003 20:30	**Cost/Denat. Gal. Ethanol**	**Ranges for Column C**					**Plant Totals**
4	**Nameplate Ethanol Prod. (Denat. Gal.)**	**40,000,000**						
5	**Investment per Nameplate Gallon**	**$1.5000**	$1.00- $2.00				**Plant Cost**	**$ 60,000,000**
6	**Factor of Nameplate Capacity**	**0.9500**	(80%- 150%)					
7	**Debt-Equity Assumptions**							
8	Factor of Equity	**0.40**						
9	Factor of Debt	**0.60**					**Initial Debt**	**$ 36,000,000**
10	Interest Rate Charged on Debt	**0.08**						
11	Rate of Return Reqd. by Investors on Equity	**0.12**						
12								
13	**Conversion Efficiency Assumptions**				**Annual Production**			
14	Anhydrous Ethanol Extracted (Gal. per Bu.)	**2.600**	2.5-2.85 gal/bu		**Bushels Ground**		**Denat. Gallons**	
15	DDGS per Bushel (lb. per Bu.)	**18**	15-22 lb./bu		**13,884,636**		**38,000,000**	
16	CO2 extracted per Bushel (lb. per Bu.)	**18**	15-22 lb./bu					
17								
18	**Establishment of Gross Margin**	**Price per Unit**			**Revenue/Bu. Ground**		**Revenue/Gal. Denatured Sold**	**Plant Totals**
19	Ethanol Price (denatured price) $/gal.	**$1.60**	$.80 to $1.60		$4.3789		1.6000	$ 60,800,000
20	DDGS Price $/T	**$169.10**	$60-$120		$1.5219		0.5561	$ 21,130,973
21	CO2 Price ($ per Ton liq. CO2)	**$6.00**	$2- $12 / liq.Ton		$0.0540		0.0197	$ 749,770
22	MN Prod. Subsidy/gal.Denat. Ethanol	**$0.00**			$0.0000		0.0000	$ -
23	Federal Small Producer Subsidy							$ -
24	CCC Bioenergy Credit							$ -
25	Revenue per Unit				$5.9548		$2.1758	**$ 82,680,743**
26	Corn Price Paid by Processor ($ per bu.)	**$4.00**	$1.70---$3.25		$4.0000		$1.4615	**$ 55,538,545**
27	Gross Margin				**$1.9548**		**$0.7143**	**$ 27,142,198**
28								
29	**Operating Expenses Per Bushel**	**Price per Unit**			**Cost /Bushel Ground**		**Cost /Gal. Denatured Sold**	**Plant Totals**
30	Natural Gas Price ($ 1,000,000 Btu)	**$10.00**	($1.50-$9.00/Dtherm)					
31	LP (Propane) Price ($ per gallon)	**$0.70**	$.55-$.72 / gal.					
32	Factor of Time Operating on Propane	**0.02**	0-.12					
33	BTU's of Heat fr Fuel Req./ Denat. Gal.	**35,000**	28,500-55,000					
34	Combined Heating Cost				$0.9534		$0.3483	$ 13,237,275
35	Electricity Price ($ per kWh)	**$0.05**	$.025-$.090/kwh					
36	Kilowatt Hours Required per Denat.Gal.	**1.090**	(.85-1.2 kWh/denat. gal.)					
37	Electrical Cost				$0.1492		$0.0545	$ 2,071,000
38	Total BTU's of Fuel and Electricity	45,900						
39	**Total Energy Cost**				**$1.1025**		**$0.4028**	**$ 15,308,275**
40		**Cost/Denat. Gal. Ethanol**						
41	Enzymes	**$0.0480**			$0.1314		$0.0480	$ 1,824,000
42	Yeasts	**$0.0220**			$0.0602		$0.0220	$ 836,000
43	Other Proc.Chemicals & Antibiotics	**$0.0200**			$0.0547		$0.0200	$ 760,000
44	Boiler & Cooling Tower Chemicals	**$0.0050**			$0.0137		$0.0050	$ 190,000
45	Water	**$0.0060**	$.005-.010		$0.0164		$0.0060	$ 228,000
46	Denaturant Price per Gal.	**$0.7000**			$0.0958		$0.0350	$ 1,329,962
47	**Total Chemical Cost**				**$0.3722**		**$0.1360**	**$ 5,167,962**
48								
49	Depreciation based on C49 asset life	**15**	Years		$0.2881		$0.1053	$ 4,000,000
50	Maintenance & Repairs	**$0.0125**			$0.0342		$0.0125	$ 475,000
51	Interest Expense				$0.2074		$0.0758	$ 2,880,000
52	Labor	**$0.0450**	$.04--$.06		$0.1232		$0.0450	$ 1,710,000
53	Management & Quality Control	**$0.0136**	$.010-$.022		$0.0372		$0.0136	$ 516,800
54	Real Estate Taxes	**$0.0020**			$0.0055		$0.0020	$ 76,000
55	Licenses, Fees& Insurance	**$0.0040**	.0030-.0050		$0.0109		$0.0040	$ 152,000
56	Miscellaneous Expenses	**$0.0135**	$.01-$.03		$0.0369		$0.0135	$ 513,000
57	**Total of Other Processing Costs**				**$0.7435**		**$0.2717**	**$ 10,322,800**
58	**Total Processing Costs**				**$2.2182**		**$0.8105**	**$ 30,799,037**
59	**Net Margin Achieved Per Unit**				**($0.2634)**		**($0.0962)**	**$ (3,656,839)**
60	**Farmer-Investor Reqd. Return on Equity**	12.00%			**$0.2074**		**$0.0758**	$ 2,880,000
61	**Increment of Success/Failure to Meet Required Return**				**($0.4708)**		**($0.1720)**	$ (6,536,839)
62								
63	**Ethanol Plant Profits for Shareholders and Principal Reduction**				**($3,656,839)**		**($3,656,839)**	**$ (3,656,839)**

Figure 2: Ethanol Plant Model

Table 2: Ethanol Profitability

Ethanol Prices

		0.80		**0.90**		**1.00**		**1.10**		**1.20**	
	1.50	(10,915,336.00)	(0.29)	(7,115,366.00)	(0.19)	(3,315,336.00)	(0.09)	484,634.00	0.01	4,284,634.00	0.11
	1.75	(13,229,513.00)	(0.35)	(9,429,513.00)	(0.25)	(5,629,513.00)	(0.15)	(1,829,513.00)	(0.05)	1,970,487.00	0.05
	2.00	(15,543,600.00)	(0.41)	(11,743,660.00)	(0.31)	(7,943,660.00)	(0.21)	(4,143,660.00)	(0.11)	(343,660.00)	(0.01)
	2.25	(17,857,808.00)	(0.47)	(14,057,808.00)	(0.37)	(10,257,808.00)	(0.27)	(6,457,808.00)	(0.17)	(2,657,808.00)	(0.07)
Corn	**2.50**	(20,171,955.00)	(0.53)	(16,371,955.00)	(0.43)	(12,571,955.00)	(0.33)	(8,771,955.00)	(0.23)	(4,971,955.00)	(0.13)
Prices	**2.75**	(22,486,102.00)	(0.59)	(18,686,102.00)	(0.49)	(14,886,102.00)	(0.39)	(11,086,102.00)	(0.29)	(7,286,102.00)	(0.19)
	3.00	(24,800,250.00)	(0.65)	(21,000,250.00)	(0.55)	(17,200,250.00)	(0.45)	(13,400,250.00)	(0.35)	(9,600,250.00)	(0.25)
	3.25	(27,114,397.00)	(0.71)	(23,314,397.00)	(0.61)	(19,514,397.00)	(0.51)	(15,714,397.00)	(0.41)	(11,914,397.00)	(0.31)
	3.50	(29,428,544.00)	(0.77)	(25,628,544.00)	(0.67)	(21,828,544.00)	(0.57)	(18,028,544.00)	(0.47)	(14,228,544.00)	(0.37)
	3.75	(31,742,692.00)	(0.84)	(27,942,692.00)	(0.74)	(24,142,692.00)	(0.64)	(20,342,692.00)	(0.54)	(16,542,692.00)	(0.44)
	4.00	(34,056,839.00)	(0.90)	(30,256,839.00)	(0.80)	(26,456,839.00)	(0.70)	(22,656,839.00)	(0.60)	(18,856,839.00)	(0.50)

Ethanol Prices

	1.50	1.30		1.40		1.50		1.60	
	1.75	8,084,634.00	0.21	11,884,634.00	0.31	15,684,934.00	0.41	19,484,683.00	0.51
	2.00	5,770,487.00	0.15	9,570,487.00	0.25	13,370,487.00	0.35	17,170,487.00	0.45
	2.25	3,456,340.00	0.09	7,256,340.00	0.19	11,056,340.00	0.29	14,856,340.00	0.39
	2.50	1,142,192.00	0.03	4,942,192.00	0.13	8,742,192.00	0.23	12,542,192.00	0.33
Corn	2.75	(1,171,955.00)	(0.03)	2,628,045.00	0.07	6,428,045.00	0.17	10,228,045.00	0.27
Prices	3.00	(3,486,102.00)	(0.09)	313,898.00	0.01	4,113,898.00	0.11	7,913,898.00	0.21
	3.25	(5,800,250.00)	(0.15)	(2,000,250.00)	(0.05)	1,799,750.00	0.05	5,599,750.00	0.15
	3.50	(8,114,397.00)	(0.21)	(4,314,397.00)	(0.11)	(514,397.00)	(0.01)	3,285,603.00	0.09
	3.75	(10,428,544.00)	(0.27)	(6,628,544.00)	(0.17)	(2,828,544.00)	(0.07)	971,459.00	0.03
	4.00	(12,742,692.00)	(0.34)	(8,942,692.00)	(0.24)	(5,142,692.00)	(0.14)	(1,342,692.00)	(0.04)
		(15,056,839.00)	(0.40)	(11,256,839.00)	(0.30)	(7,456,839.00)	(0.20)	(3,656,839.00)	(0.10)

The data in Table 2 are then used to find a relationship between corn and ethanol prices and profitability. To do this we use every combination in the table of ethanol and corn prices with the profitability to create a regression data file. The two X-variables are corn and ethanol prices with the Y-variable being profitability. By doing this we can find the relationship between corn and ethanol prices with regard to the plant's profitability.

The regression results show the relationship between corn and ethanol prices and profitability as follows:

$$P = -.723 + 1E - .243C$$

T-Stat: (-420) (840) (-659)

Adjusted $R^2 = 0.999$

where P is the profitability ($/gal.), E is ethanol price ($/gal.), and C is corn price ($/bu.).

The regression explains all the variance in the data, which is what one would expect. In fact, it is only due to rounding that it was possible to do the regression. The reason the data is practically 100 % correlated is that the independent variables, corn and ethanol prices, are linked to the dependent variable, profitability, only by linear transformations in the spreadsheet model. That is, profitability is a non-varying linear function of corn and ethanol prices. However, because of rounding, we were able to get a regression, which gives us the statistical summary of all the calculations in the spreadsheet model, which is what we were seeking.

Variable Subsidy

This equation can be used to create a model for a variable subsidy. This is the primary equation that will be used to determine what subsidy payments would be needed as corn and ethanol prices change. Corn and ethanol prices can be entered into this equation to figure out what the plant should receive as a subsidy payment for any given profit level. A profit amount is included to provide flexibility in the subsidy model. The new equation would be:

$$S = -.723 - P + 1E - .243C$$

Where S is the subsidy payment ($/gal.), and P is the stipulated additional profit level ($/gal.). This additional profit level (beyond the assumed 12% return on equity) is essentially a political choice variable with the level set in a political balancing act. For our analysis, the profit was set at $.20 per gallon of ethanol produced for most of the simulations.[2] With this amended equation we can now enter in ethanol and corn prices, and additional profit as $.20, and calculate what the subsidy payment would need to be so that the plant will be able to cover costs and make an additional profit of $.20 per gallon of ethanol produced. By amending the equation this way, a more realistic variable rate subsidy model can be used.

Table 3 illustrates the model calculation of subsidy payments for a span of five months. The Monthly Subsidy Payment column used the above equation with corn and ethanol prices for that month as inputs.

Table 3: Monthly Variable Subsidy Payment

	Monthly Average Corn Price	Monthly Average Ethanol Price	Monthly Subsidy Payment
Jan-04	$2.39	$1.23	$0.28
Feb-04	$2.61	$1.27	$0.29
Mar-04	$2.75	$1.32	$0.27
Apr-04	$2.89	$1.27	$0.35
May-04	$2.87	$1.33	$0.29

Quarterly Subsidy

Another variant of the model calculates ethanol subsidy payments on a quarterly basis. To create a workable subsidy payment program, the time period for each payment needs to be extended from monthly payments to quarterly payments. To do this, all of the input variables for the regression equation need to be averaged into quarters of a year. For the above equation, $S = -.725 - P + 1E - .243C$, corn and ethanol prices must be averaged. The prices for the preceding 3 months determine the next quarter's subsidy. This means that if a quarter begins in April, the average prices of January, February, and March are used to determine the second quarter subsidy. Once the quarter prices are determined, they can be entered into the equation to determine what the quarter subsidy payment should be. Table 4 illustrates the model calculation of quarterly subsidy payments.

[2] Our analysis was done for a 40 million gal./yr. plant. Capital costs decline as plant size increases to about 100 million gal./yr. Larger plants would have higher profits, and most plants being built today are larger than 40 million gal./yr.

Table 4: Quarterly Variable Subsidy Payment

	Monthly Average Corn Price	Quarterly Average Corn Price	Monthly Average Ethanol Price	Quarterly Average Ethanol Price	Quarter Subsidy Payment
Jan-04	$2.39		$1.23		
Feb-04	$2.61		$1.27		
Mar-04	$2.75	$2.58	$1.32	$1.27	$0.28
Apr-04	$2.89		$1.27		
May-04	$2.87		$1.33		
Jun-04	$2.79	$2.85	$1.32	$1.31	$0.31

In Table 4, the $.28 subsidy calculation done in March 2004 will be the subsidy payment for the months of April, May, and June. The $.28 subsidy payment was calculated using the quarter average corn and ethanol prices from the months of January, February, and March.

Subsidy Using Gasoline Prices

This model to this point uses market ethanol prices to determine the subsidy payment. Historically, the ethanol market has been relatively thin. To overcome this potential problem, we also developed a relationship between ethanol and gasoline prices so that ethanol prices can be estimated based on gasoline prices. This is a potential improvement to the model because historically, the gasoline market has been more robust than the ethanol market.

In order to determine a relationship between gasoline and ethanol a regression was run using historic average prices with ethanol being the dependant variable and gasoline the independent variable. The following equation was created from the regression:

$$E = .908 + .356G$$

T-Stat: (32.79) (10.01)

Adjusted $R^2 = .457$

where E is ethanol price and G is gasoline prices, both in $/gal.[3]

This equation allows for gasoline prices to be used to determine an estimated ethanol price to be entered into the subsidy payment equation. This creates a variable rate subsidy program calculated from corn and gasoline prices.

Interpretation of Variable Subsidy Results

In this section we use the economic models discussed earlier to compare the costs and benefits of the current flat rate ethanol subsidy with a variable rate subsidy. Several versions of the variable subsidy will be tested:

- A monthly version based on monthly corn and ethanol prices. This version was mainly used to test the model
- A quarterly version based on quarterly corn and ethanol prices
- A quarterly version based on quarterly gasoline and corn prices.

[3] Gasoline data was from the Energy Information Administration (DOE), and ethanol prices were from a confidential industry source.

The current flat rate ethanol subsidy of $.51 per gallon is not completely efficient in most cases. The only time the flat rate subsidy is completely efficient is when profit is $-.51, which, of course is rare. This means that all other payments are either too large, thus adding additional cost to the government, or too small and not meeting producers needs.

Figure 3 illustrates the price combinations of corn and ethanol for when a subsidy is needed. The area under the line provides the price combinations of corn and ethanol in which a subsidy payment is needed. The area above the line is price combinations in which no subsidy payment is needed. This line would shift up if we increased the additional profit variable, P.

Locus of Zero Subsidy Ethanol and Corn Prices

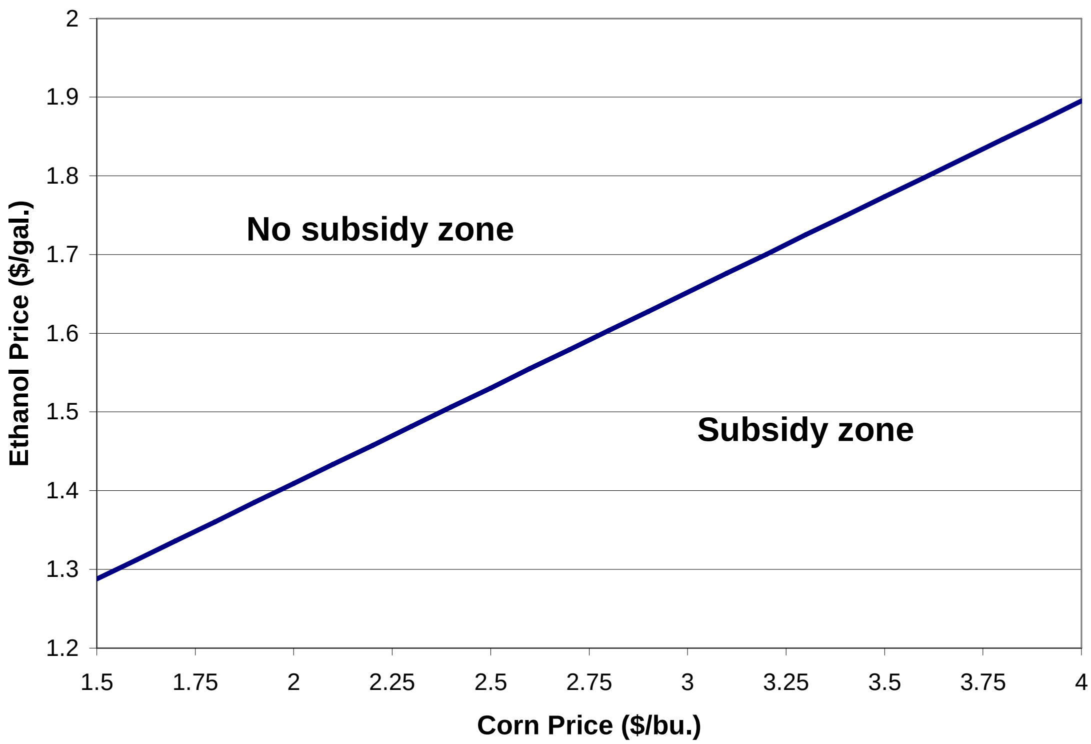

Figure 3: Locus of Zero Subsidy Ethanol and Corn Prices

As discussed above, a variable rate subsidy could potentially be more efficient in reducing risk for the private sector and cost for the government. This can be seen in Figure 4.

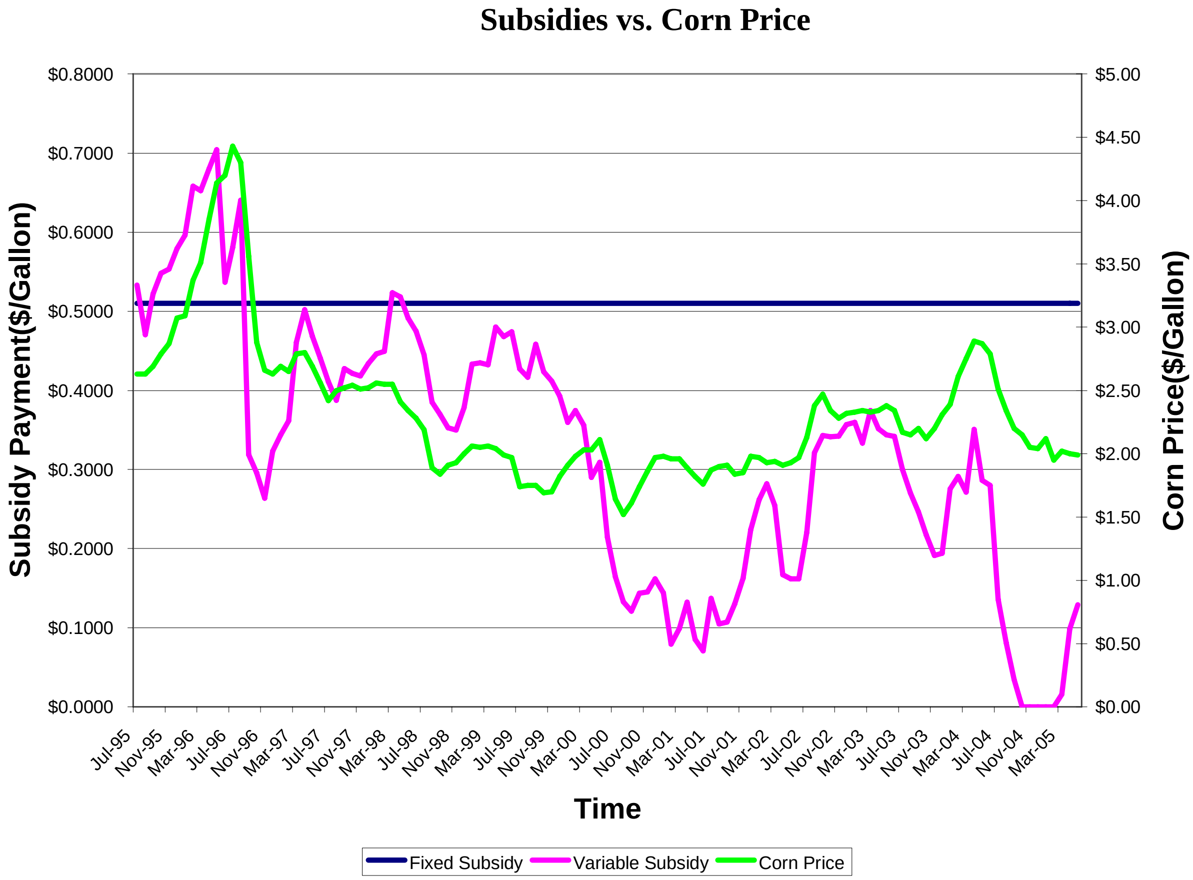

Figure 4: Ethanol Subsidies and Corn Prices

For the historical data, the monthly variable rate subsidy payments move in very similar trends to corn prices. This is important because corn is the key input in ethanol production and thus a major cost. A subsidy payment that moves in line with corn trends will be much more efficient than one that doesn't.

A variable rate subsidy also creates a possibility for government savings with regard to subsidy payments. A measure of government savings can better be done using the monthly variable rate subsidy model. Historic monthly average ethanol and corn prices can be used to calculate what variable subsidy payments would have been in the past by entering these into the equation, S = -.723 -P + 1E -.243C, introduced above. Historic prices have been acquired back to July of 1995 and used as inputs for this model. When compared to the flat rate subsidy, the calculated variable rate subsidy was less than \$.51 88% of the time. This means that when using a monthly variable rate subsidy, 88% of the months between July 1995 and May 2005, some amount of government savings was observed. This can also be seen in Figure 5.

Figure 5 illustrates that 88% of the months between July 1995 and May 2005, when the variable rate subsidy was less than the flat rate subsidy. During five of those months, October 2004 to February 2005, no subsidy payments would have been paid with a variable rate subsidy due to the favorable market prices of corn and ethanol. In 2004, 3.4 billion gallons of ethanol were produced, which would be a monthly average of 283 million gallons. Our subsidy cost comparison over 10 years assumes 3.4 billion gallons per year for the fixed and variable rate subsidy.

Fixed Subsidy vs. Variable Subsidy

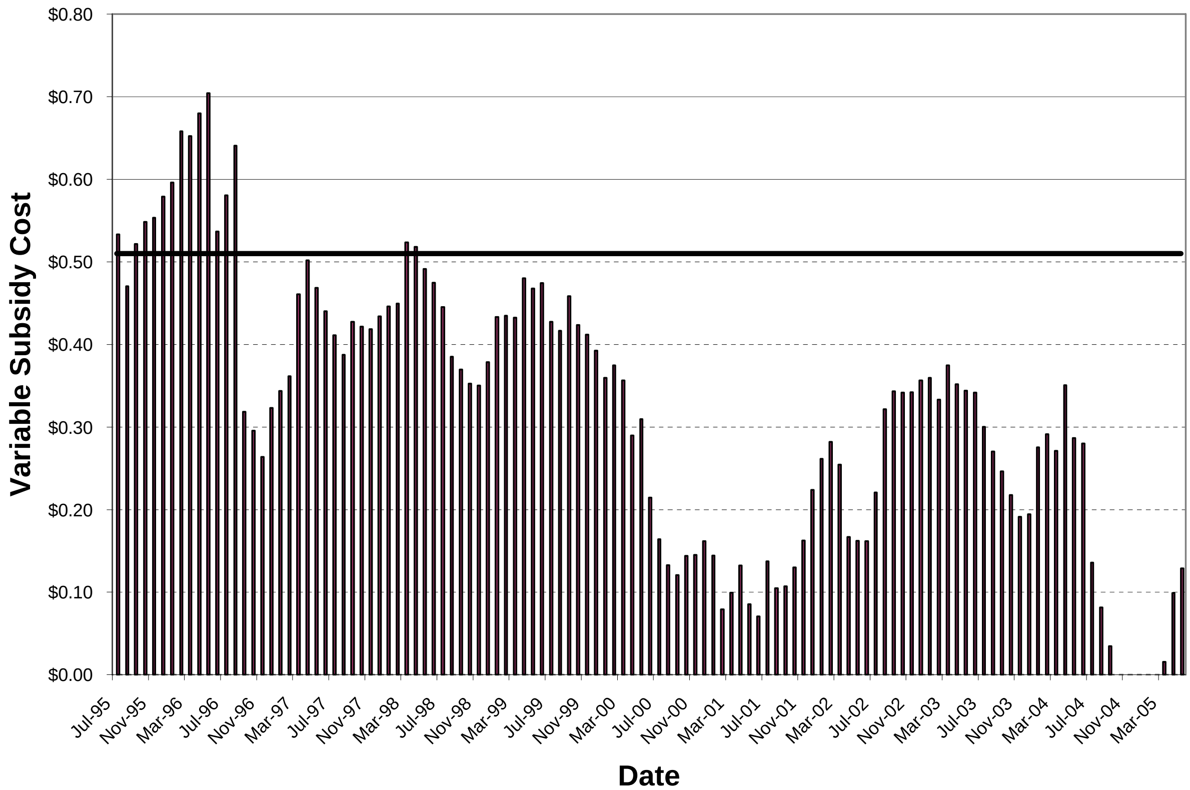

Figure 5: Fixed and Variable Subsidy Cost

Using the 3.4 billion gallons of ethanol produced in 2004 as the production base, total government savings between July 1995 and May 2005 can be estimated. This amount is multiplied to the variable rate subsidy payment for each month to calculate a monthly subsidy cost for the government. The fixed subsidy, $.51 can be multiplied by the 283 million gallons to calculate the monthly subsidy cost. The monthly amounts for both the fixed and variable subsidy are summed to calculate the total subsidy cost from July 1995 to May 2005. When doing this, the fixed subsidy cost was $17,195,500,000 while the monthly variable subsidy cost was $10,826,582,000. This is a total subsidy cost savings of $6,368,918,000, which is an annual average savings of $642 million, or 37%.

This model is a monthly payment model, which may not be feasible for the government to implement. A more workable model would be a quarterly model in which the preceding quarter's prices would determine next quarter's prices. For example, the average corn and ethanol prices for January, February, and March would determine the next quarter's subsidy payment. This introduces more error for the subsidy calculation, which is undesirable; however, it is much more feasible for the government to administer a quarterly subsidy program than one that is monthly.

The results for the quarterly subsidy are almost identical to the results from the monthly subsidy. With historical data, the total cost of the quarterly subsidy is $10,856,850,000, which is an annual cost of $1,094,808,000 while the total cost of the monthly subsidy is $10,822,582,000 which is an annual cost of $1,091,756,000. This is an average difference of $3,052,000 annually, or 0.3%.

A comparison between the monthly and quarterly average subsidy payments can also be done with regard to government savings. The average government savings for each monthly average subsidy payment is $.19 with a standard deviation of .17. The average government savings for each quarterly average subsidy payment is $.19 with a standard deviation of .16. These calculations show that a quarterly average subsidy payment is almost identical to a monthly average payment with regard to government savings. This also shows that the quarterly subsidy payment is similar enough to the monthly payment to be a justified replacement allowing the government to have a more feasible variable subsidy program.

A measurement of risk assumed by the producer can also be calculated for both the flat rate and variable rate subsidies. To compare risk between the flat and variable rate subsides, profitability must first be calculated. To calculate profitability the following equations are used:

- Flat rate subsidy:
  Profit = -.723 + FSP + EP - .243 * CP
- Variable rate subsidy:
  Profit = -.723 + VSP + EP - .243 * CP

where FSP is the flat rate subsidy payment ($.51), VSP is the variable subsidy payment. EP is the monthly average ethanol price, and CP is the monthly average corn price, as before.

Historic prices from July 1995 to May 2005 can be used as inputs for the equation to calculate what profit would be historically for each month. Trends for both the flat rate and variable rate subsidies can be seen in Figure 6.

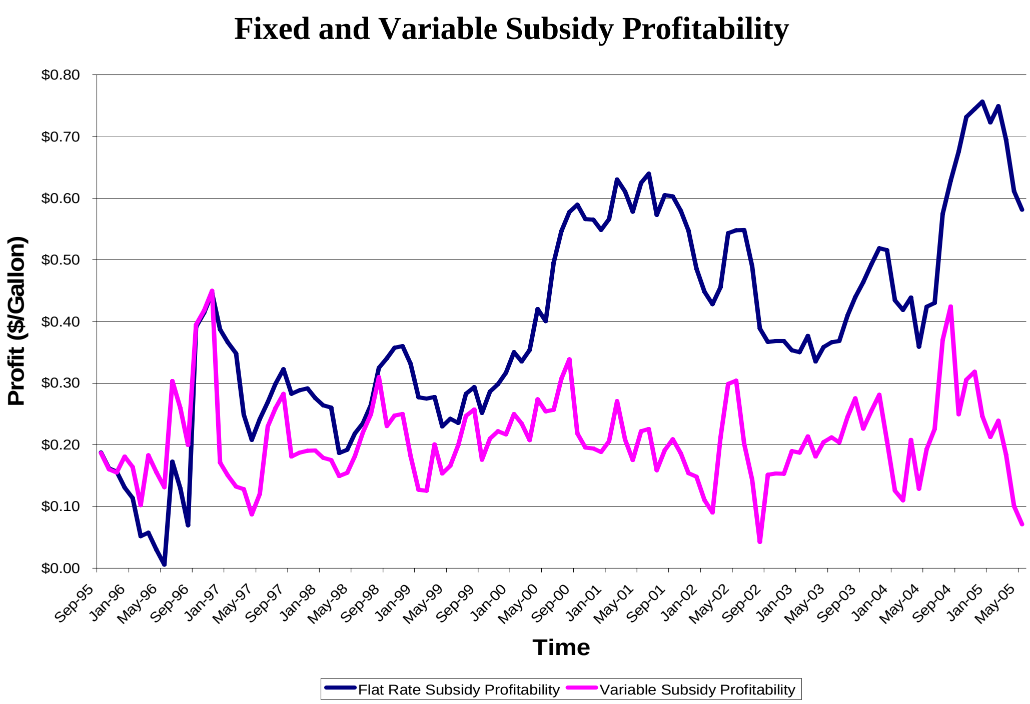

Figure 6: Fixed and Variable Subsidy Profitability (ethanol-corn subsidy)

The average monthly profit for the flat rate subsidy is $.39 with a standard deviation of .17. The average monthly profit for the variable rate subsidy is $.21 with a standard deviation of .07 (with additional profit equal to $0.20). The average profit is higher for the flat rate subsidy, which is what is expected. The coefficient of variation can also be used as a measure of variability. The coefficient of variation for the flat rate subsidy is 0.43 while for the variable subsidy it is 0.34. The standard deviation and coefficient of variation for the variable rate subsidy is much lower than the flat rate subsidy, which is a clear indication that the variable subsidy payment reduces private risk. Since the coefficient of variation is lower for the variable rate subsidy, the risk assumed by the producer is also lower. This means that the variable rate subsidy has reduced government cost while at the same time reduced the risk faced by producers.

We did the analysis using a subsidy that changed quarterly and assumed different levels of additional profit. Table 5 summarizes the results of this analysis for different levels of addition al profit.

The results show:

- The variable subsidy reduces government cost uniformly across these data.
- The lower the value of additional profit, the higher the cost savings for the government and the lower is the expected profitability.
- The variability in private sector profitability (a measure of risk) as measured by the coefficient of variation (CV) of profit is always lower with the variable subsidy as compared with the fixed subsidy, as would be expected.
- Expected profitability is reduced or held constant depending on the value of additional profit (P).

In other words, we can hold expected profit and government cost about the same and significantly reduce producer risk, or we can lower expected profit, lower government cost, and lower producer risk all at the same time but to differing degrees.

Table 5: Ethanol Profitability, Risk Reduction, and Government Cost

Item		Fixed Subsidy	Variable Subsidy with Alternative Levels of Additional Profit, P		
			$0.20	$0.30	$0.38
Average producer profit/gallon		$0.39	$0.21	$0.31	$0.39
Reduction in producer profit			-46%	-21%	0%
Variability of producer profit (CV)		0.43	0.34	0.23	0.18
Change in profit variability (CV)			-21%	-47%	-58%
Government cost per gallon		$0.51	$0.32	$0.42	$0.50
Change in government cost			-37%	-18%	-2%

Note: CV is the standard deviation of profits divided by the mean.

The last adjustment made to the variable rate subsidy was using an ethanol price series based on a regression between gasoline and ethanol prices. This allows for ethanol prices to be estimated from gasoline prices. A subsidy based on gasoline and corn would be based on two extremely solid markets, whereas a subsidy program based on corn and ethanol would not be as solid due to the historically thin nature of the ethanol market. A visual relationship between the actual ethanol price, estimated ethanol price, and gasoline can be seen in Figure 7.

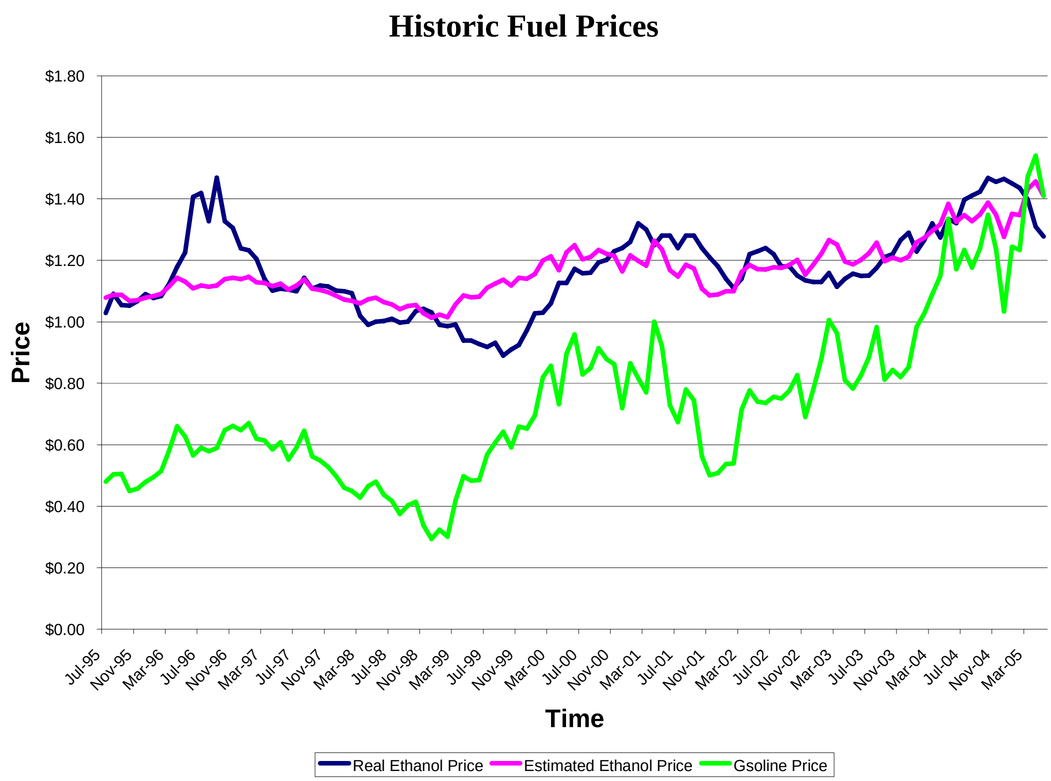

Figure 7: Historic Fuel Prices

The trends for both estimated and real ethanol are extremely similar, which is desirable. This means that a subsidy with estimated ethanol prices derived from the gasoline market are similar to a subsidy based on real ethanol prices and that the subsidy based on estimated ethanol prices is an acceptable replacement for the subsidy based on real ethanol prices, at least based on historic data. As ethanol markets become more robust, it may be desirable to use the ethanol price directly.

A comparison can be made between the costs of the two quarterly subsidy programs. Using historic prices, the total cost of the gasoline-corn quarterly subsidy is $10,804,177,000 which is an annual cost of $1,089,497,000. The total cost of the ethanol-corn quarterly subsidy was $10,856,851,000 which is an annual cost of $1,094,808,000. This is a difference in annual cost of $5,311,000, or 0.5%

A comparison can also be made between the government savings of the two quarterly subsidy programs. The average government savings for each gasoline-corn quarterly subsidy payment when compared to the $.51 flat rate subsidy is $.19 with a standard deviation of .18. The average government savings for each ethanol-corn quarterly subsidy payment when compared to the $.51 flat rate subsidy is $.19 with a standard deviation of .164. The difference in variance is most likely due to using estimated ethanol prices rather than real prices. However, the difference in standard deviation is extremely small, which indicates that this is an acceptable subsidy program when compared to the actual ethanol price subsidy model.

A comparison can also be done between profitability and risk of the two quarterly subsidy programs. Similar to the corn-ethanol quarterly subsidy, profit can be found using the same formulas for the corn-gasoline quarterly subsidy and using historic prices as inputs. Trends in profit for the corn-gasoline subsidy and fixed subsidy are shown in Figure 8.

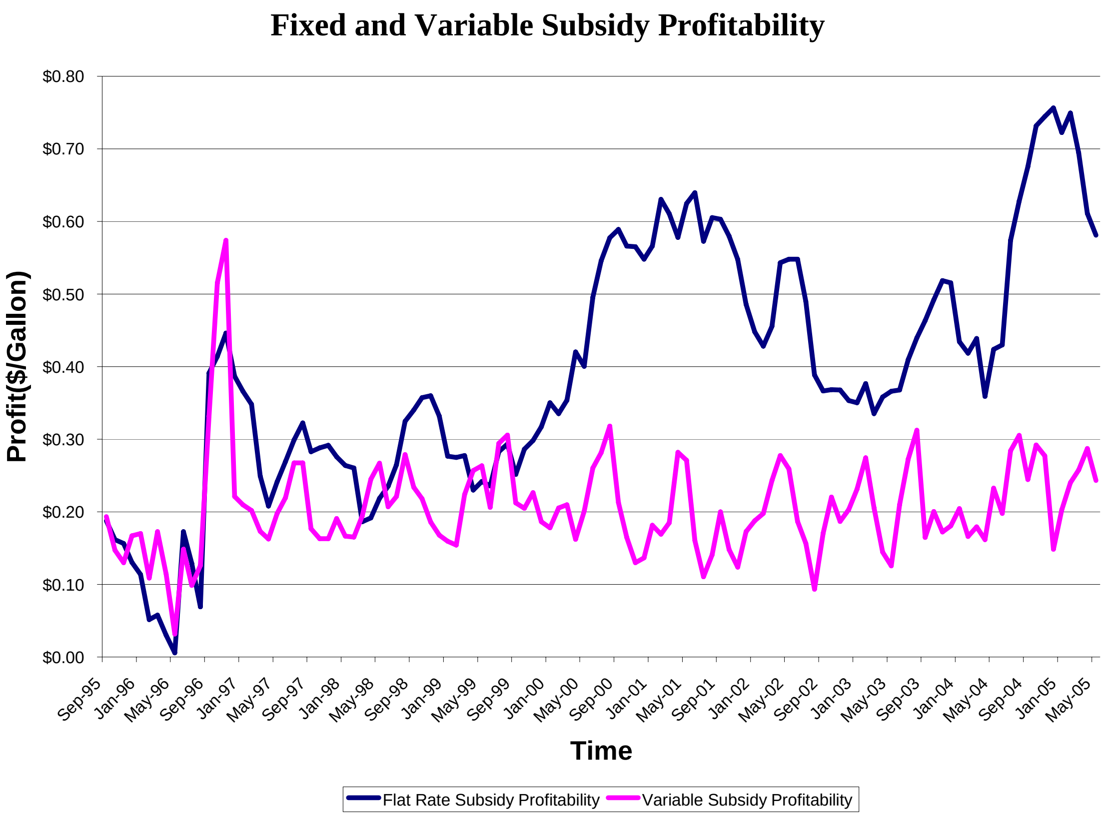

Figure 8: Fixed and Variable Subsidy Profitability (gasoline-corn subsidy)

The trend lines for both the corn-ethanol and corn-gasoline variable subsidies are very similar. The statistical results are identical. The average profit is $.21 with a standard deviation of .07 and a coefficient of variation of .34 for both variable subsidies. This means that both variable rate subsidies have effectively reduced risk assumed by producers.

The results of the analysis have indicated that both variable rate subsidies have reduced government cost substantially as well as reduced risk seen by producers. Both of these results were goals of creating a variable rate subsidy. The variable rate subsidy allows for a feasible subsidy program to be implemented by the federal government that is both beneficial for producers and for the government.

If the variable subsidy were in effect today, the cost for the first half of 2006 would have been zero; yet, the private sector would still be insured against future oil price drops or corn price increases. However, with the Renewable Fuels Standard requiring 4 billion gallons of renewable fuels to be produced in 2006, and if all that were ethanol, the subsidy cost for 2006 would be $2.04 billion.

Conclusions

This research has shown that there is inefficiency with the current flat rate ethanol subsidy and that a variable rate subsidy has the potential for being more efficient. The variable rate subsidy would be more efficient for both the federal government and ethanol producers in that government savings would be 37% while the risk assumed by producers was reduced by 21%.

This research also has a few limitations that need to be addressed. One area that needs to be addressed is that the subsidy was based on only one profit model, the Tiffany-Eidman model from The University of Minnesota. Any error in that one model could lead to errors within the variable subsidy. However, the model has been widely used. Another limitation is that we used a historical relationship between corn and the DDGS prices. As the DDGS market becomes flooded as ethanol production increases, this relationship may not always be completely accurate.

This research also leaves room for further research to be done in the future. One area that could be researched further is deciding what the optimal added profit level should be within the variable ethanol subsidy. The analysis in this research generally uses $0.20/gallon produced as the extra profit level. Further research could develop sensitivity analysis on the profit level.

This research also relies on current ethanol production costs and production efficiencies. As the ethanol industry continues to develop, the Tiffany-Eidman profit model may not remain accurate. As advancements are made in this industry, the variable subsidy model discussed in this research will have to be updated to accommodate these changes.

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