An Analysis of Price Behavior in the United States Peanut Industry

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Introduction

Historically U.S. peanut industry operated in a regulatory environment directly affecting peanut production and marketing
- The marketing quota system and associated price supports affected the peanut quantity produced and peanut prices received by growers

2002: Significant changes in the U.S. peanut industry regulatory environment
- The elimination of marketing quotas and associated price supports
- The industry shifted to a more market-oriented environment

Objective

To evaluate peanut price behavior in the period following the industry deregulation in 2002
- To quantify the fundamental relationship between peanut price and production
- Inverse demand framework is used to analyze peanut price-quantity relationship in a market-oriented environment

Data

USDA National Agricultural Statistics Service
- Peanut price, peanut production, peanut area harvested and yield
- Yearly data for the period of 1980 to 2016

Methodology

1. Descriptive statistical analysis of the peanut industry trends during two periods
- 1980-2001 (a period prior to the industry deregulation in 2002) and
- 2002-2016 (a market-oriented industry environment)
- Averages and coefficients of variation are calculated for peanut price, production, yield and area harvested

2. Econometric analysis of peanut price behavior during the period of 2003-2016
- Estimation of peanut price-quantity relationship using inverse demand function (i.e. price-dependent demand function)
- For the period of 2003-2016, including 2003-2009 and 2010-2016 as two sub-periods

Descriptive Statistical Analysis

Table 1. U.S. peanut industry: Area harvested, yield, production and price (1980-2016)

Period	Acres harvested	Yield	Production	Price
	thousand	pounds per acre	billion pounds	$ per pound
	Average (Coefficient of Variation)			
1980-2001	1.530 (0.111)	2,483 (0.126)	3.786 (0.140)	0.277 (0.089)
2002-2016	1.335 (0.148)	3,395 (0.136)	4.549 (0.225)	0.217 (0.199)

Changes in the industry performance in 2002-2016, as compared to 1980-2001

- The yearly average peanut area harvested decreases by 13%
- The yearly average peanut yield increases by 37%
- The yearly average peanut production increases by 20%
- The yearly average peanut price decreases by 22%

Econometric model #1
The effect of peanut production on peanut price

$P_t = \alpha + \beta \times Q_t + \varepsilon_t$
P_t is peanut price in year t ($ per pound)
Q_t is peanut quantity (billion pounds) produced in year t
In the inverse demand framework
α is expected to be positive
β is expected to be negative

Table 2. The effect of peanut production on peanut price: OLS estimation results

	2003-2009	2010-2016	2003-2016
Constant	0.17* (4.65)	0.29* (4.28)	0.19* (3.63)
Production	0.006 (0.61)	-0.010 (-0.66)	0.006 (0.51)
R2	0.04	0.05	0.02
Sample Size	7	7	14

T-ratios are in the parentheses.
*Indicates statistical significance at 10% level using a two-tailed T-test.

2003-2009 estimation results are not consistent with inverse demand framework
2010-2016 estimation results are consistent with inverse demand framework
- A low explanatory power of the estimated model
- The coefficient for production has expected negative sign (it is not statistically significant)
  - 1 billion pounds increase (decrease) in peanut production causes peanut price to decrease (to increase) by $0.010 per pound

Econometric model #2:
The effects of peanut area harvested and yield on peanut price

$P_t = \alpha_0 + \beta_1 \times Acres_t + \beta_2 \times Yield_t + u_t$
P_t is peanut price in year t ($ per pound)
$Acres_t$ is the number of peanut acres harvested (million acres) in year t
$Yield_t$ is peanut yield (thousand pounds per acre) in year t
α_0 is expected to be positive
β_1 and β_2 are expected to be negative

Table 3. The effects of peanut acres harvested and yield on peanut price: OLS estimation results

	2003-2009	2010-2016	2003-2016
Constant	-0.061** (-1.53)	0.25** (1.63)	0.11 (1.17)
Acres	-0.014 (-0.75)	-0.10 (-1.26)	-0.075** (-1.49)
Yield	0.088* (9.19)	0.035 (1.04)	0.061* (3.07)
R2	0.84	0.18	0.40
Sample Size	7	7	14

T-ratios are in the parentheses.
*Indicates statistical significance at 10% level using a two-tailed T-test.
**Indicates statistical significance at 10% level using a one-tailed T-test.

The coefficient for peanut area harvested is negative, as expected
The coefficient for peanut yield is positive (contradicts the expected negative sign)
2003-2009 estimation results
- Changes in peanut yield have a stronger effect on peanut price than changes in peanut area harvested
2010-2016 estimation results
- Changes in peanut area harvested have a stronger effect on peanut price than changes in peanut yield

Conclusion

Trends in the U.S. peanut industry performance:
2002-2016, as compared to 1980-2001
- The yearly average peanut production to increase
- The yearly average peanut price to decrease
- The volatility of peanut production and peanut price to increase
The industry performance during the period of 2010-2016 tends to be consistent with inverse demand framework
- An increase in peanut quantity produced causes a decrease in peanut price: Representative production seasons 2011-2012, 2013-2014 and 2014-2015
- A decrease in peanut quantity produced causes an increase in peanut price: Representative production season 2010-2011

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Abstract

This research paper analyzes the fundamental relationship between peanut price and peanut production in the U.S. peanut industry during the period of 2003-2016, which followed the industry deregulation that took place in 2002 (i.e. the implementation of the Federal peanut quota buyout program and the elimination of associated price supports). The inverse demand framework is used to evaluate the peanut price-quantity relationship at the growers' level of the peanut supply chain in a market environment free of the government programs directly affecting the peanut quantity produced.

Key words: Peanut economics, peanut marketing, peanut pricing.

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1. Introduction

During many decades the U.S. peanut industry experienced a substantial degree of the Federal government intervention in peanut production and marketing. The marketing quota system and associated price supports affected the peanut quantity produced and peanut prices received by peanut growers (Dohlman and Livezey, 2005; Dohlman et al., 2009). In 2002, Federal government implemented a quota buyout program, which led to the elimination of marketing quotas. As a result, the U.S. peanut industry shifted to a more market-oriented environment (Schnepf, 2016). The research objective is to quantify the fundamental relationship between peanut price and peanut production in the U.S. peanut industry during the period of 2003-2016, which followed the industry deregulation (i.e. the quota buyout program) in 2002.

The inverse demand framework is used to evaluate the U.S. peanut industry developments in a market-oriented environment. This theoretical framework predicts that commodity price is a function of the commodity quantity produced, and there is inverse relationship between price and quantity (Moore, 1919). The inverse demand framework was used to analyze price behavior in the cotton industry (Moore, 1919), potato industry (Pavlista and Feuz, 2005; Loy et al., 2011; Bolotova, 2017) and onion industry (Bolotova and Jemmett, 2010).

Peanut price received by peanut growers each year is hypothesized to be a function of the peanut quantity produced each year. A negative effect of changes in peanut production on peanut price is expected: an increase (a decrease) in peanut production would lead to a decrease (an increase) in peanut price received by peanut growers. A linear regression model is used to quantify the price-quantity relationship in the U.S. peanut industry. The peanut price flexibilities are computed for representative market scenarios. The peanut price flexibilities can be used to evaluate peanut price behavior in the future.

2. Research Methodology

The economic variables used in the empirical analysis include: peanut acres harvested, peanut yield measured in pounds per acre, peanut production (quantity) measured in pounds and peanut price received by growers measured in $ per pound. These economic variables at the national level on a yearly basis are reported by the U.S. Department of Agriculture National Agricultural Statistics Service (2017). The reported peanut prices are survey-based prices corresponding to the farmer-first-handler level of the peanut supply chain.

At the first stage, a descriptive statistical analysis is used to evaluate changes in the economic variables characterizing industry performance between two periods. The period of 1980-2001 represents a period prior to the quota buyout program implemented in 2002. The period of 2002-2016 represents a period following the quota buyout program. The yearly averages and the coefficients of variation are calculated for each economic variable for both periods.

At the second stage, to quantify the effect of changes in peanut production on peanut price received by growers, an econometric model represented by equation (1) is estimated. This econometric model represents a linear inverse demand function (i.e. price-dependent demand function) of the U.S. peanut industry at the farm-gate stage of the peanut supply chain.

(1) $P_t = \alpha + \beta \times Q_t + \varepsilon_t$.

P_t is peanut price in year t ($ per pound), Q_t is peanut quantity (billion pounds) produced in year t, and ε_t is the error term. α is the constant; it is expected to be positive. β is the coefficient to be estimated for peanut quantity (production); it is expected to be negative in the inverse demand framework. In a linear econometric model, β is a marginal effect (dP/dQ). In this research setting the expected negative coefficient would indicate a $ per pound increase (decrease) in peanut price,

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which follows a 1 billion pounds decrease (increase) in peanut production. α and β are the intercept and slope, respectively, of the inverse demand curve on a graph.

Given that the total peanut production is a product of the number of acres harvested and yield per acre, an alternative approach to analyze the effect of changes in peanut production on peanut price is to include peanut acres harvested and peanut yield per acre as independent variables in the econometric model, instead of including the total peanut quantity produced. Equation (2) presents this alternative econometric model to be estimated.

(2) $P_t = \alpha_0 + \beta_1 \times Acres_t + \beta_2 \times Yield_t + u_t$.

P_t is peanut price in year t ($ per pound), $Acres_t$ is the number of peanut acres harvested (million acres) in year t, $Yield_t$ is peanut yield (thousand pounds per acre) in year t, and u_t is the error term. α_0 is the constant; it is expected to be positive. β_1 is the coefficient to be estimated for peanut acres harvested, and β_2 is the coefficient to be estimated for peanut yield. Both β_1 and β_2 are expected to be negative. In this research setting the expected negative magnitude of β_1 would indicates a $ per pound increase (decrease) in peanut price, which follows a 1 million acres decrease (increase) in the peanut area harvested. The expected negative magnitude of β_2 would indicate a $ per pound increase (decrease) in peanut price, which follows a 1 thousand pounds decrease (increase) in peanut yield per acre.

The estimated coefficient for peanut production (β) in the inverse demand function (equation (1)) can be used to calculate the peanut price flexibility using formula (3). Price flexibility indicates a percentage increase (decrease) in price, which follows a 1% decrease (increase) in quantity.

(3) $F_{P,Q} = (dP/dQ) \times (Q/P) = \beta \times (Q/P)$.

3. Results and Discussion

3.1. Descriptive Statistical Analysis

Table 1 summarizes the yearly averages and coefficients of variation for peanut acres harvested, yield, production and price calculated for 1980-2001 (active marketing quota system and associated price supports) and 2002-2016 (a market-oriented environment). During the period of 1980-2001, the yearly average area harvested is approximately 1.530 million acres, the yearly average yield is 2,483 pounds per acre, the yearly average production is 3.786 billion pounds and the yearly average peanut price is $0.277 per pound. During the period of 2002-2016, the yearly average peanut production increases to 4.549 billion pounds (a 20% increase). While the yearly average area harvested decreases to 1.335 million acres (a 13% decrease), the yearly average yield increases to 3,395 pounds per acre (a 37% increase). An increase in the yearly average total peanut production is associated with a decrease in the yearly average peanut price to $0.217 per pound in 2002-2016 (a 22% decrease relative to 1980-2001).

The coefficients of variation characterize the volatility of the analyzed economic variables. The increases in the volatility of all analyzed economic variables are observed in 2002-2016, as compared to 1980-2001. As indicated by the observed changes in the coefficients of variation, the volatility of the peanut area harvested increases by 34%, and the volatility of peanut yield increases by 8%. The volatility of peanut production increases by 61%, and the volatility of peanut price increases by 123%.

3.2. Econometric Analysis: Estimation Results

Table 2 summarizes the Ordinary Least Squares (OLS) estimation results for the econometric model explaining the effect of changes in peanut production on peanut price (equation 1). Table 3 summarizes the OLS estimation results for the econometric model explaining the effects of

changes in peanut acres harvested and peanut yield on peanut price (equation 2). The econometric

models are estimated for the period of 2003-2016 and for two sub-periods within this period: 2003-

2009 and 2010-2016. 2002, the year of the implementation of the quota buyout program, is not

included in the data set used in the econometric analysis.

Econometric Models Explaining the Effect of Peanut Production on Peanut Price (Table 2)

As indicated by the coefficients of determination (R^2), the explanatory power of all three

econometric models is very low: R^2 is in the range of 2% to 4%. The constants are positive, as

expected, and are statistically significant. The estimated coefficients for peanut production are not

statistically significant in all three models. The estimated coefficient for peanut production is 0.006

in the econometric models estimated for 2003-2009 and for 2003-2016. The positive sign of this

coefficient contradicts the hypothesized inverse relationship between peanut price and production.

The estimated coefficient for peanut production is -0.010 in the econometric model estimated for

2010-2016. The magnitude of this coefficient is consistent with the inverse demand framework.

This coefficient is interpreted as follows: a 1 billion pounds increase (decrease) in peanut

production causes a $0.010 per pound decrease (increase) in peanut price received by growers

during the period of 2010-2016.

Econometric Models Explaining the Effects of Peanut Acres Harvested and Peanut Yield on

Peanut Price (Table 3)

As indicated by the coefficients of determination (R^2), the explanatory power of these econometric

models is 84% for 2003-2009, 18% for 2010-2016 and 40% for 2003-2016. The estimated

coefficient for peanut acres harvested is negative, as expected, in all three models. This coefficient

is statistically significant in the econometric model estimated for 2003-2016, and it is close to be

statistically significant in the econometric model estimated for 2010-2016. The estimated

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coefficient for peanut yield is positive in all three models, which contradicts the expected negative effect. This coefficient is statistically significant in the econometric models estimated for 2003-2009 and 2003-2016.

The estimation results reveal the following general pattern charactering the U.S. peanut industry developments during the transition period, immediately following the marketing quota buyout program in 2002. During the period of 2003-2009, changes in peanut yield have a stronger effect on peanut price, as compared to changes in peanut acres harvested. The estimated coefficient for peanut yield is 0.088, and it is statistically significant: a 1,000 pounds per acre increase (decrease) in peanut yield causes a $0.088 increase (decrease) in peanut price in 2003-2009.

During the period of 2010-2016, changes in peanut acres harvested have a stronger effect on peanut price, as compared to changes in peanut yield. The estimated coefficient for peanut acres harvested is -0.10. The coefficient has expected negative sign, and it is very close to exhibiting statistical significance: a 1 million acres increase (decrease) in the peanut area harvested causes a $0.10 per pound decrease (increase) in peanut price during the analyzed period. A shift to a stronger acreage effect on peanut price during 2010-2016 is likely to contribute to the observed negative (though not statistically significant) coefficient for peanut production in the inverse demand function estimated for 2010-2016.

The pattern of peanut price-quantity relationship observed in the period of 2010-2016 tends to be consistent with the inverse demand framework. Figure 1 depicts an inverse demand curve corresponding to the estimated inverse demand function for 2010-2016. Two representative market scenarios reflecting the industry performance consistent with the inverse demand framework are indicated on Figure 1. A representative market scenario in which a decrease in peanut production

causes peanut price to increase is observed in 2010-2011. A representative market scenario in which an increase in peanut production causes peanut price to decrease is observed in 2014-2015.

3.3. Peanut Price Flexibilities

The structure of the inverse demand function estimated for 2010-2016 in general is consistent with the theoretical predictions. Using the estimated coefficient for peanut production -0.010, the yearly average price of $0.242 per pound and the yearly average production of 5.087 billion pounds for 2010-2016, the average peanut price flexibility is calculated using formula (3). The average peanut price flexibility is -0.21, indicating that a 1% increase (decrease) in peanut production causes a 0.21% decrease (increase) in peanut price during the period of 2010-2016.

An alternative approach to calculate price flexibilities is to use yearly prices and quantities for the years when the industry performance is consistent with the expected inverse relationship between peanut price and quantity. This approach does not require estimating inverse demand function. In this case, price flexibility is calculated using formula (4), which is a re-arranged version of formula (3).

(4) $F_{P,Q} = \dfrac{\% \text{ change in P}}{\% \text{ change in Q}}$

The years in which the U.S. peanut industry performance reflects the inverse relationship between price and quantity include: 2003-2004, 2004-2005, 2005-2006, 2010-2011, 2011-2012, 2013-2014 and 2014-2015. During these years, two types of typical market scenarios are observed. The first one is characterized by an increase in peanut production, which is followed by a decrease in peanut price: 2003-2004, 2004-2005, 2011-2012, 2013-2014 and 2014-2015. The second one is characterized by a decrease in peanut production, which is followed by an increase in peanut price:

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2005-2006 and 2010-2011. Peanut price, peanut quantity and peanut price flexibilities for these years are reported in Table 4.

The price flexibilities are approximately the same in 2004 and 2005: -0.60 and -0.62, respectively. The price flexibilities in the most recent years, 2014 and 2015, are -0.48 and -0.78, respectively. The extreme values of the price flexibilities are -0.08 and -0.06 in 2006 and 2012, respectively, and -3.45 in 2011. These price flexibilities provide ideas about possible ranges of peanut price response to changes in peanut production.

4. Conclusion

The empirical evidence presented in the paper indicates that the U.S. peanut industry performance changed following the implementation of the Federal quota buyout program in 2002. In the post-2002 period, there is a trend for the yearly average peanut production to increase and the yearly average peanut price to decrease. The volatility of both peanut production and peanut price increases.

The period following the quota buyout program can be characterized as a market oriented environment or perhaps "transition" period, because the industry does not adjust to changes in the regulatory environment immediately. In a market oriented environment, an industry's performance can be evaluated using the inverse demand framework. The commodity price that producers receive is a function of this commodity quantity produced: an increase (a decrease) in production causes price to decrease (to increase). Empirical evidence indicates that the U.S. peanut industry performance during the period of 2010-2016 tends to be consistent with the inverse demand framework. The reported peanut price flexibilities can be used to evaluate peanut price behavior in the future.

Even though the reported empirical findings for the most recent years tend to be consistent with the theoretical predictions, they should be used with caution, because statistical performance of the econometric models is somewhat low. A small sample size and the fact that the industry experienced significant structural changes might have affected statistical performance of the econometric models. Nevertheless, the reported empirical results are useful in understanding the U.S. peanut industry performance during the transition period and can be used to evaluate the peanut price-quantity relationship in the future. The analysis presented in the paper can be reproduced in the future to monitor peanut price developments.

While empirical results based on a simple economic model provide a good insight into the price determination process in the modern U.S. peanut industry, it is important to recognize that this process also reflects a complex interaction of industry and policy forces. They include individual production and marketing decisions of peanut growers, changes in peanut area planted and peanut yield, competition from alternative crops, the Federal government programs affecting domestic peanut industry and developments in international peanut markets.

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Table 1. U.S. peanut industry:
Peanut area harvested, yield, production and price (1980-2016).

Period	Acres harvested	Yield	Production	Price
		pounds per acre	pounds	$ per pound
		Average (CV)		
1980-2001	1,530,036 (0.111)	2,483 (0.126)	3,785,674,591 (0.140)	0.277 (0.089)
2002-2016	1,335,380 (0.148)	3,395 (0.136)	4,548,727,467 (0.225)	0.217 (0.199)

CV is the coefficient of variation: it is the ratio of standard deviation to the mean.

Table 2. The effect of peanut production on peanut price: OLS estimation results.

	2003-2009	2010-2016	2003-2016
Constant	0.17* (4.65)	0.29* (4.28)	0.19* (3.63)
Production	0.006 (0.61)	-0.010 (-0.66)	0.006 (0.51)
R2	0.04	0.05	0.02
DW statistic	0.62	1.03	0.64
Sample Size	7	7	14

T-ratios are calculated using autocorrelation-adjusted standard errors (Newey-West approach).
*Indicates statistical significance at 10% level using a two-tailed T-test; T-statistic cut-off value is |1.943|.

Table 3. The effects of peanut acres harvested and yield on peanut price:
OLS estimation results.

	2003-2009	2010-2016	2003-2016
Constant	-0.061** (-1.53)	0.25** (1.63)	0.11 (1.17)
Acres	-0.014 (-0.75)	-0.10 (-1.26)	-0.075** (-1.49)
Yield	0.088* (9.19)	0.035 (1.04)	0.061* (3.07)
R2	0.84	0.18	0.40
DW statistic	1.39	1.24	1.16
Sample Size	7	7	14

T-ratios are calculated using autocorrelation-adjusted standard errors (Newey-West approach).
*Indicates statistical significance at 10% level using a two-tailed T-test; T-statistic cut-off value is |2.015|.
**Indicates statistical significance at 10% level using a one-tailed T-test; T-statistic cut-off value is |1.476|.

Table 4. U.S. peanut industry: Peanut price flexibilities.

Year	Price	Production	Change in Price	Change in Production	Price flexibility
	$ per pound	pounds	%	%	
2003	0.193	4,144,150,000			
2004	0.189	4,288,200,000	-2.07	3.48	-0.60
2005	0.173	4,869,860,000	-8.47	13.56	-0.62
2006	0.177	3,464,250,000	2.31	-28.86	-0.08
2010	0.225	4,156,840,000			
2011	0.318	3,658,590,000	41.33	-11.99	-3.45
2012	0.301	6,753,880,000	-5.35	84.60	-0.06
2013	0.249	4,173,170,000			
2014	0.22	5,188,665,000	-11.65	24.33	-0.48
2015	0.193	6,001,357,000	-12.27	15.66	-0.78
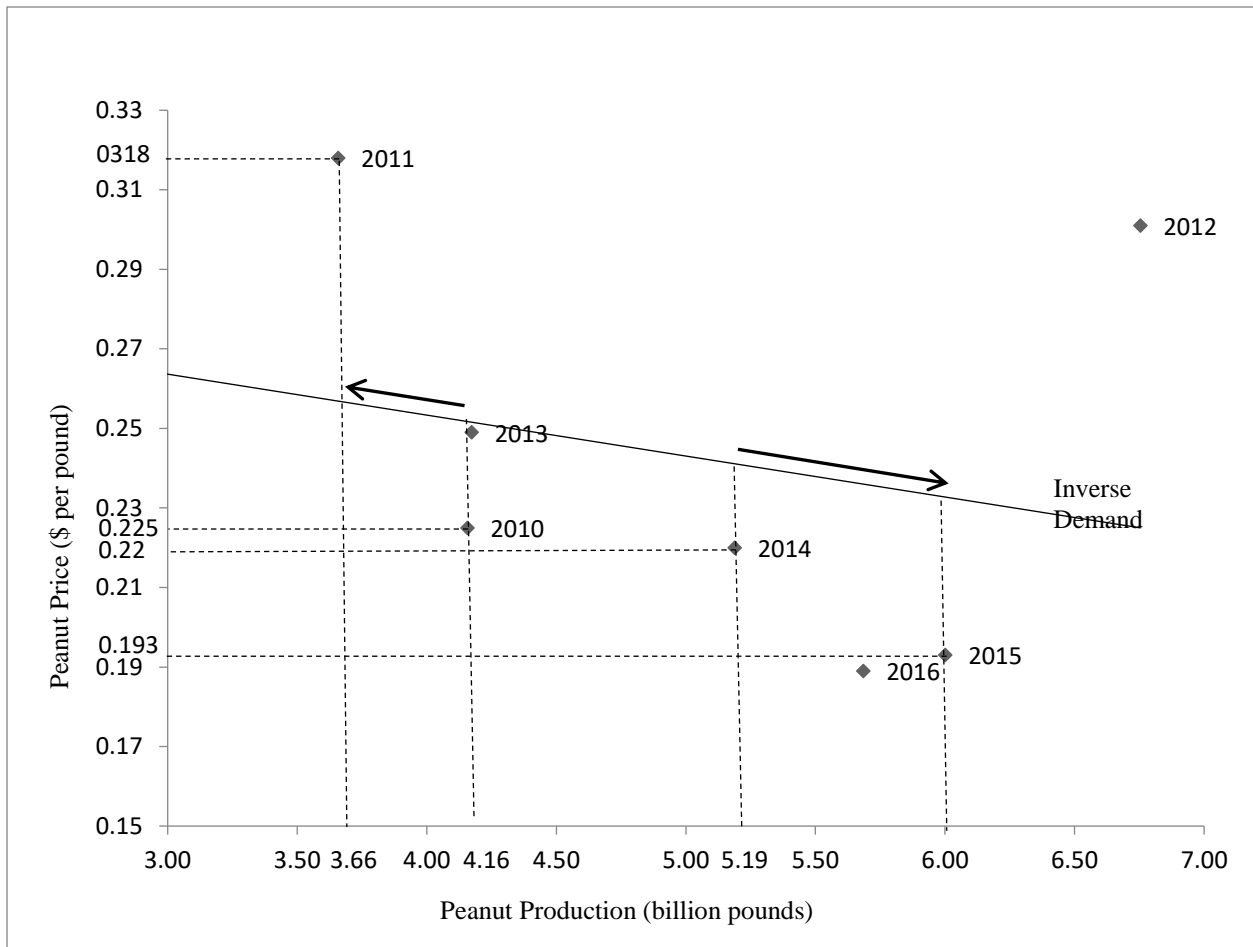
Figure 1. U.S. peanut industry (2010-2016): Peanut price, peanut production and inverse demand curve. Two representative market scenarios: 2010-2011 (a decrease in production is followed by an increase in price) and 2014-2015 (an increase in production is followed by a decrease in price).