Informa Economics IEG
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The Impact of Ethanol Industry Expansion on Food Prices: A Retrospective Analysis

Prepared for:

THE RENEWABLE FUELS ASSOCIATION

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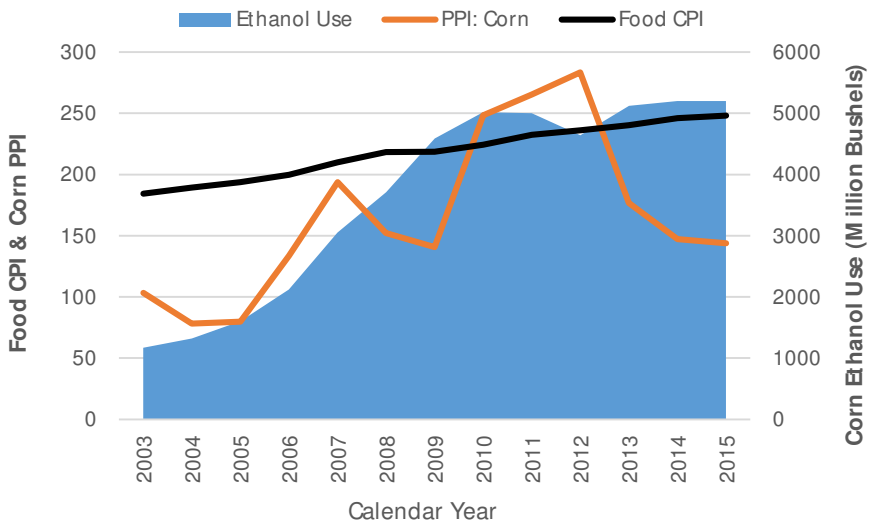
I. KEY FINDINGS

THE BUILD-OUT OF THE GRAIN-BASED ETHANOL INDUSTRY IN THE UNITED STATES IS LARGELY COMPLETE. LOOKING BACK, WHAT EFFECT HAS ETHANOL HAD ON FOOD PRICES?

Based on this analysis, retail food prices were not impacted in any demonstrable way by expansion of U.S. grain ethanol production under the Renewable Fuel Standard (RFS) over the past decade. This conclusion is supported by the generally weak statistical relationship between corn prices and consumer food prices, and the fact that ethanol expansion was just one of many factors driving corn prices over the past 10 years. In fact, consumer food price inflation has decelerated over the course of the last decade.

- Increasing ethanol production has impacted corn supply-and-demand fundamentals and, by extension, corn prices over the last decade. However, ethanol has not been the sole driver of corn markets.
  - Among the drivers, weather is particularly notable.
- During the period of the grain-based ethanol industry build-out, corn prices increased from 2005 to 2007, fell during the latter part of 2008 and 2009, and then rose again (Exhibit 1). The increase in the use of corn in ethanol slowed dramatically starting in 2010, but corn prices did not hit record levels until 2012, primarily as a result of a drought that affected much

Exhibit 1: Corn Ethanol Use, Corn PPI, & Food CPI

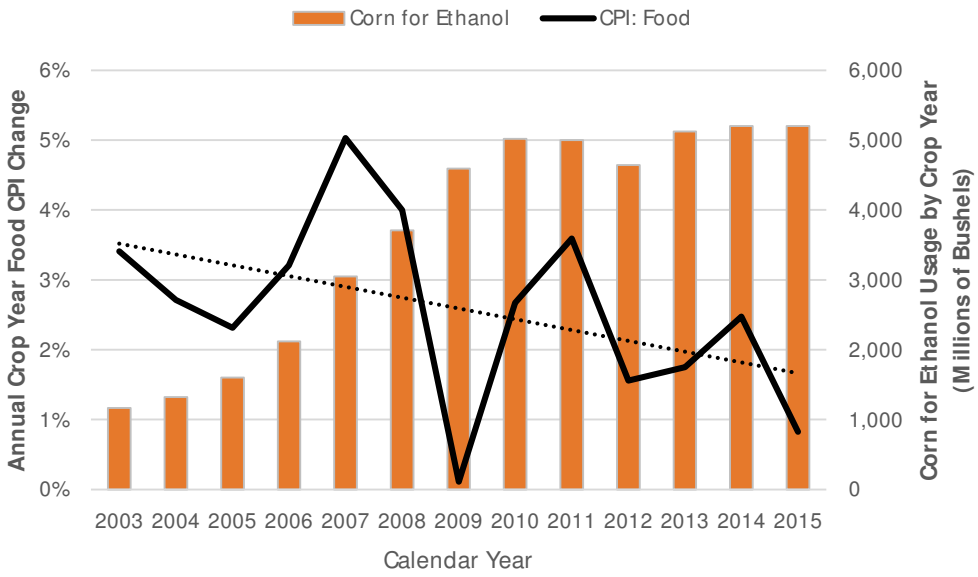


Source: Informa Economics IEG

of the U.S. that year. Notably, by 2015 corn prices had dropped to levels experienced early in the time period, despite ethanol production remaining essentially stable.

- Despite these fluctuations in corn prices, the Consumer Price Index (CPI) for food increased virtually unabated over the course of the time period. Statistical analysis shows that the link between corn prices and overall food prices has been weak.
  - The increase in the food CPI actually decelerated as the usage of corn in ethanol production increased dramatically (Exhibit 2).
  - A key reason for the weak linkage between corn prices and consumer food prices is that the farm share of the overall food dollar is only 10%. A large majority of the food dollar is accounted for by the costs of transforming farm products to retail grocery products, along with transportation and distribution at various levels of the supply chain.
  - Margin adjustments by players along the supply chain also helped insulate consumers from the full pass-through of higher commodity prices. Notably, the livestock industry has undergone inventory adjustments and periods of unfavorable margins as a result of higher feed costs (again, due not only to ethanol but also to weather and other factors).

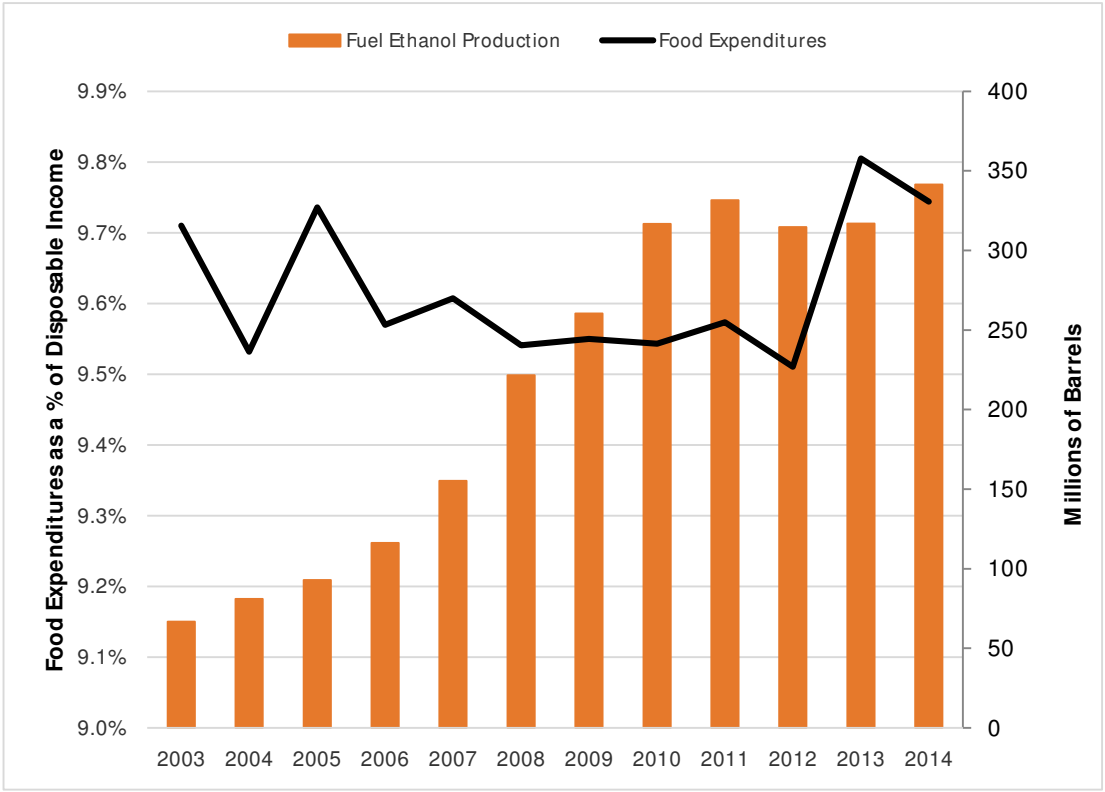
Exhibit 2: Food CPI: Annual % Change and Ethanol Usage



Source: Informa Economics IEG

- Notably, the share of disposable income spent on food declined to 9.5% in 2012 from 9.7% in 2003, despite the sizable increase in ethanol production (Exhibit 3). The share spent on food rebounded starting in 2013, but the build-out had largely ended by then.

Exhibit 3: Food Expenditures and Ethanol Production



Source: USDA ERS, and Informa Economics IEG

II. BACKGROUND

Purpose of the Study

- The Renewable Fuel Standard was established in the Energy Policy Act of 2005. Two years later, the Energy Independence and Security Act of 2007 (EISA) expanded the previous biofuel usage targets dramatically and allocated the expanded standard (now known as RFS2) among specific categories of biofuels. There are four standards within RFS2, which specify the volumes of biomass-based diesel (mainly biodiesel) and cellulosic biofuels that must be used, along with requirements for the total consumption of advanced biofuels (defined as having 50% lower greenhouse gas emissions) and renewable fuels as a whole.
  - There is no specific requirement for the use of corn-based ethanol. Rather, it is eligible to be used toward the total renewable fuel standard but not the total advanced biofuel standard.
- Expansion of the grain-based ethanol industry began to pick up in the middle part of the last decade, and it accelerated following the establishment of the Renewable Fuel Standard. However, the build-out was essentially complete by the end of 2010.
  - Production of corn-based ethanol has now nearly reached the 15-billion-gallon cap for which it is eligible under RFS2.
- A number of reports and articles regarding the impact of biofuel production on commodity prices and consumer food costs were published in near real-time over the last decade, as biofuel production was rising rapidly and commodity prices were still at elevated levels. Given that the build out of the grain-based ethanol industry has essentially stopped and that global commodity inventories have been replenished, it is a good point in time to conduct a retrospective analysis of what occurred. The Renewable Fuels Association (RFA) commissioned Informa Economics IEG (Informa) to conduct this analysis.

A Note on Methodology

- Two related statistical measures are used in this analysis: the correlation coefficient and the R-squared (R^2) statistic.

- The correlation coefficient measures the degree and direction of the linear relationship between two variables. A coefficient of 1 indicates perfect positive correlation, while a coefficient of -1 indicates perfect negative correlation. A score of zero indicates the absence of a mathematical relationship between the two variables.
- R-squared measures the degree of fit of a linear regression to the data. An R^2 of 1 indicates perfect fit, while an R^2 of 0 indicates no relationship. It can be interpreted as indicating the degree to which variation in a variable can be "explained" by a model; for example, an R^2 of 0.5 would indicate that 50% of the variation in the dependent variable is "explained" by movement in the independent variable(s) in the regression. Because it is calculated using the squared values of the residuals (i.e., the differences between the actual and predicted values), the R^2 typically appears lower than the absolute value of the correlation coefficient. Specifically, for a regression with a single independent variable, the R^2 is equal to the correlation coefficient squared.

III. THE RELATIONSHIP BETWEEN ETHANOL PRODUCTION AND CORN PRICES

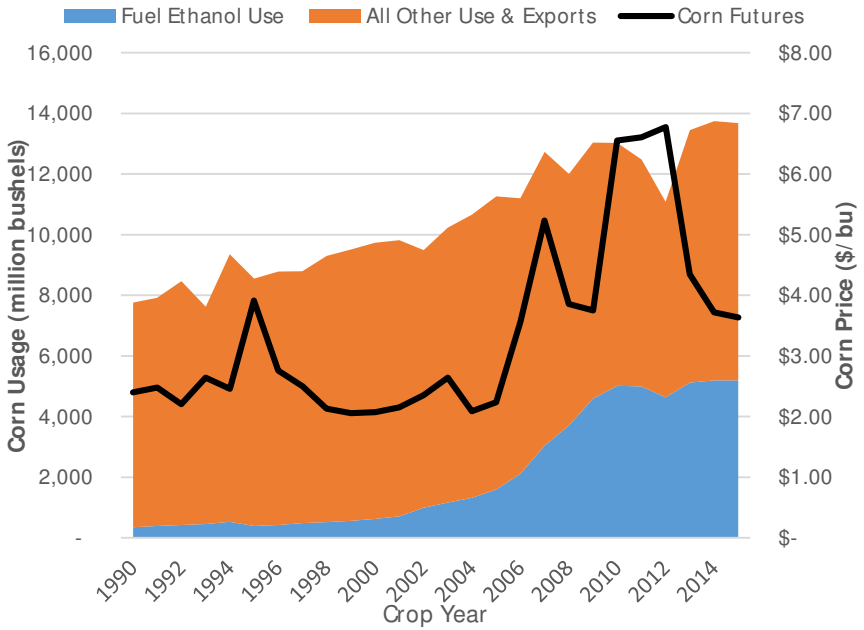
WHAT IMPACT HAS ETHANOL HAD ON CORN PRICES?

The build-out of the ethanol industry impacted corn supply-and-demand fundamentals and, by extension, corn prices. However, it was not the sole driver. Weather has always been a driver of price fluctuations, and it was a major cause of price increases at times over the last decade. With the build-out of the grain-based ethanol industry having essentially stopped, corn prices have now adjusted, returning to levels experienced in the early years of the RFS.

Corn Usage in Ethanol Production & Corn Prices

- The use of corn in ethanol production rose substantially over the last decade as a result of high energy prices and the establishment of the Renewable Fuel Standard.
- In crop-marketing year 2015/16, the usage of corn for ethanol and byproducts accounted for 38% of total corn usage on a gross basis, double the 19% level in 2006/07 (pre-RFS2).
  - Since 2009/10, corn usage in ethanol has remained between 35% and 42% of total corn usage on a gross basis.
  - As noted, these estimates are on a gross basis and do not reflect the return of roughly one-

Exhibit 4: Historical Corn Usage and Price



Source: USDA, Informa Economics IEG

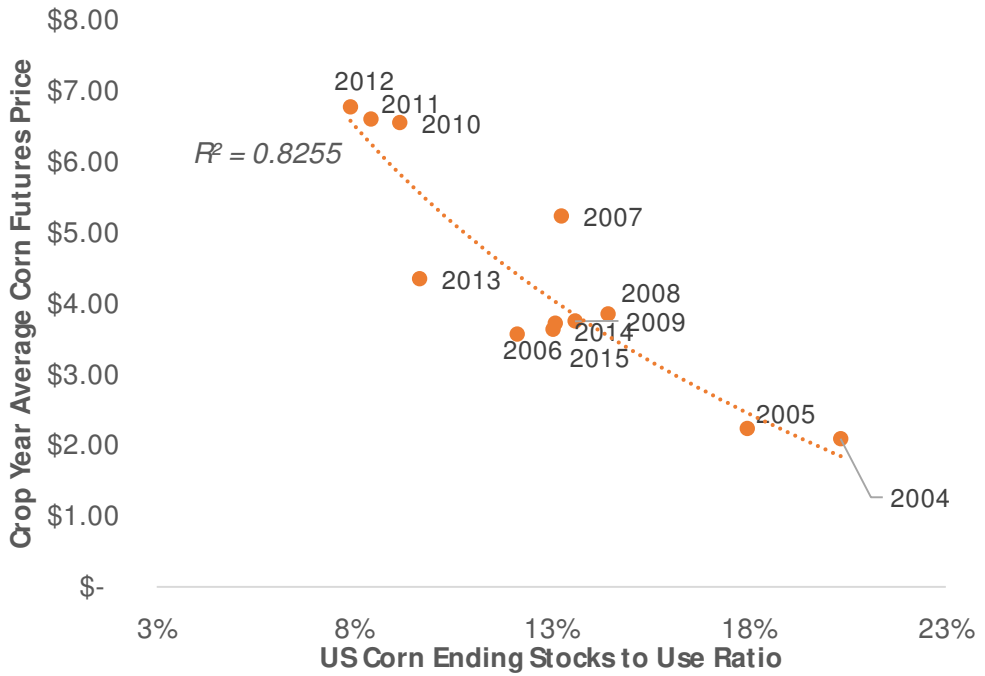
third of the corn kernel to the market as byproducts for use in feed.

- Corn prices generally were elevated from crop year 2006/07 to 2012/13 due to several factors, although they were quite volatile.
  - This volatility continued even after the end of the build-out of the ethanol industry. Futures increased from $3.72 per bushel (bu) in crop year 2009/10 to a record $6.74/bu in 2012/13 (largely as a result of the U.S. drought) but then fell back to $3.69/bu by 2015/16.

Corn Ending Stocks-to-Use Ratio vs. Corn Price

- The U.S. corn ending stocks-to-use ratio is a key measure of supply/demand pressures.
  - As the stocks-to-use ratio declines (i.e., supplies tighten relative to demand), there is upward pressure on corn prices. The opposite is true in years where supplies are abundant relative to demand, causing downward pressure on prices.
- Again, ethanol is only one of the factors that affect corn supply and demand, and thereby prices.
  - Other major factors affecting corn supply, demand and price include: weather (U.S. and overseas), conditions in the livestock-and-poultry sector, global shocks (other than weather) and energy prices. Energy prices

Exhibit 5: Corn Ending Stocks/Use Ratio vs. Corn Price



Source: USDA, Informa Economics IEG

affect not only ethanol but also crop-production costs and soybean oil prices (via biodiesel production), which is notable since corn and soybeans compete for acreage. A recap of the myriad of factors that affected corn prices during and after the ethanol industry build-out is provided in Exhibit 6.

Exhibit 6: Key Drivers of Corn Prices During and After the Ethanol Industry Build-Out

Corn Futures ($/bu)	Change (prev. year)	Key Supply / Demand Drivers of Corn Prices	
		Key Upward Price Pressure Factor(s)	**Key Downward Price Pressure Factor(s)**
2004/05			
$2.12	↓ -0.52		• Record corn yields and production.
2005/06			
$2.23	↑ +0.12	• Return to historically consistent yields resulted in a decline in corn production. • Higher corn usage in ethanol production. • Higher exports.	• Production still 2nd highest on record.
2006/07			
$3.56	↑ +1.32	• Lower corn production. ✓ Low prices in the two previous years resulted in lower acreage. • Persistent weather concerns. • Higher crude oil prices. • Higher corn usage in ethanol production. • Poor Australian wheat crop.	• Lower feed and residual usage.

Corn Futures ($/bu)	Change (prev. year)	Key Supply / Demand Drivers of Corn Prices	
		Key Upward Price Pressure Factor(s)	**Key Downward Price Pressure Factor(s)**
2007/08			
$5.15	↑ +1.59	• Higher corn usage in ethanol production. • Higher feed and residual usage. • Higher exports. ✓ World wheat supply reductions.[1] Poor Australian wheat crop for 2nd year in a row. ✓ Lower U.S. dollar. • Strong increase in crude oil prices to record level.	• Higher corn production due to acreage increase.
2008/09			
$3.93	↓ -1.22	• Higher corn usage in ethanol production. • Lower corn production due to a decline in acreage. ✓ High crude oil prices led to high soybean oil prices, incentivizing a shift to soybean planting.	• Lower feed and residual usage. ✓ Due to recession as well as livestock inventory reductions following high corn prices. • Lower exports. • Decline in crude oil price after crop was planted.
2009/10			
$3.72	↓ -0.21	• Higher corn usage in ethanol production. • Slight increase in exports.	• Above-trend yields and record supplies. • Lower feed and residual usage. ✓ Due to the recession as well as further cattle herd reductions.
2010/11			
$6.47	↑ +2.76	• Lower crop yields. • Moderately higher corn use in ethanol production. • Higher crude oil prices. • Lowest ending stocks-to-use ratio since 1995/96.	• Lower feed and residual usage. ✓ Due in part to Southern Plains drought. • Weak exports.

[1] U.S. wheat supplies were reduced by adverse weather, including a spring freeze and unseasonably heavy rainfall around harvest. Additionally, Australia's wheat production had fallen significantly due to drought. Eastern Europe, Ukraine, and to some extent Canada – all of which are large-scale wheat producers – were also experiencing supply issues.

Corn Futures ($/bu)	Change (prev. year)	Key Supply / Demand Drivers of Corn Prices	
		Key Upward Price Pressure Factor(s)	**Key Downward Price Pressure Factor(s)**
2011/12			
$6.57	↑ +0.09	• Below-trend yields. • Further decline in ending stocks-to-use ratio.	• Usage declined across the board ✓ Ethanol ✓ Feed and residual ✓ Exports
2012/13			
$6.74	↑ +0.17	• Widespread drought led to yields far below trend. ✓ 3rd consecutive year of yield declines. • Further decline in ending stocks-to-use ratio.	• Usage declined across the board again ✓ Ethanol ✓ Feed and residual ✓ Exports
2013/14			
$4.41	↓ -2.33	• Feed and residual usage increased for the first time since 2007/08.	• Higher production ✓ Yields in line with long-term trend.
2014/15			
$3.75	↓ -0.66		• Record crop yields and production. • Strong world supplies and record Brazil exports.
2015/16			
$3.69	↓ -0.06	• Lower production due to reduction in acreage.	• Relatively stable demand.

IV. THE RELATIONSHIP BETWEEN CORN PRICES AND THE PRICES OF OTHER COMMODITIES

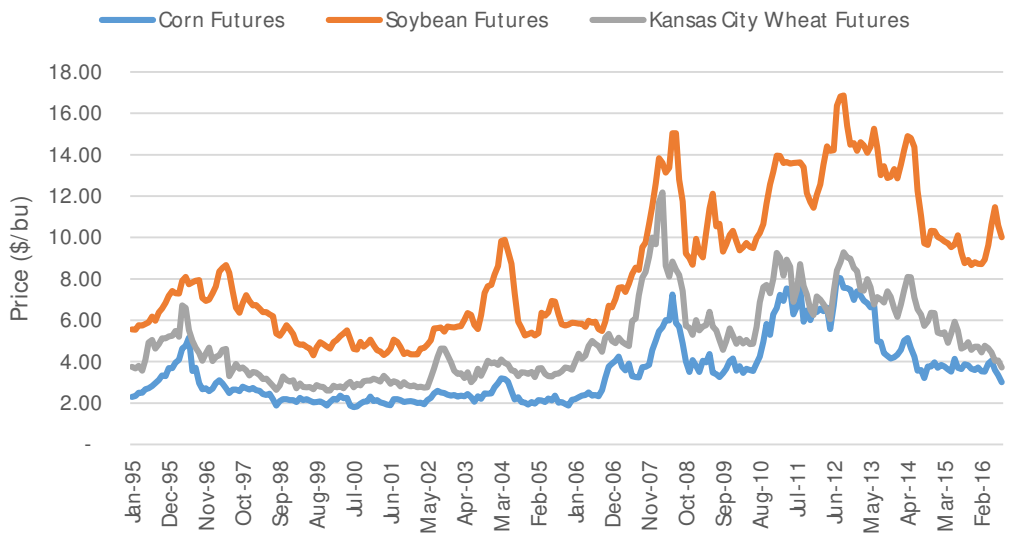
WHAT INFLUENCE DO CORN PRICES HAVE ON OTHER COMMODITIES?

Corn prices are related to other crop prices, particularly soybeans. They also have a direct impact on feed costs and, along with other variables, have thereby impacted livestock margins and inventories. This has had some effect on livestock prices, although the statistical relationships are weak.

Corn, Soybeans and Wheat

- As the three largest row crops in the U.S., a general relationship exists among the prices of corn, soybeans and wheat.
  - One reason for the relationship is the competition for acreage among the three crops. This is particularly the case for corn and soybeans.
  - Additionally, weather conditions will often affect more than one crop.

Exhibit 7: Corn, Soybean, and Wheat Prices



Source: Informa Economics IEG

- Energy costs are another common variable. Energy has long been a key input cost component across all three crops. With the emergence of the ethanol

and biodiesel industries, the demand for corn and soy bean oil as feedstocks has resulted in a stronger linkage to the petroleum market.

- Although corn is a feed grain and wheat is a food grain, there is some level of substitutability. Modest amounts of wheat are used as feed in the U.S., but it is more common in other parts of the world. When a weather problem occurs in one or more countries where wheat and barley are used extensively in feed, this can necessitate increased usage of other feed grains, including corn. For example, global wheat supplies were reduced by adverse weather in 2007, causing higher demand for U.S. corn exports and thus higher prices.

Livestock, Poultry and Dairy Prices

- Corn prices have a direct impact on feed costs, which impact livestock production margins. However, there is frequently not a direct and immediate transmission of these feed costs to livestock prices. Margins are impacted, and production cycles delay the impact.

- Livestock inventories have been affected by the high corn prices at times over the last decade. However, just as corn prices were not driven solely by ethanol, conditions in the livestock sector were influenced by more than just feed prices. For example, the Great Recession in 2008 and 2009 affected meat demand, and drought in the Southern Plains in 2010 and 2011 adversely affected the cattle sector even before the 2012 drought resulted in widespread problems across both the crop and livestock sectors.

- The impact of high corn prices can be absorbed through margin compression for a while, but eventually high feed costs led to livestock inventory reductions. This led to a short-term increase in meat production due to herd liquidation. However, over time, as these supply adjustments worked their way through the system, livestock prices and meat prices began to reflect the new market supply/demand dynamics.

Agricultural Commodity Price Correlations

- Exhibit 8 illustrates commodity price correlations across two time periods: 2003-2015 and 2008-2015. The longer period has a starting point prior to the establishment of the original RFS, while the shorter time period begins immediately after passage of RFS2.

- Additionally, two methods were used in estimating the correlations: direct price correlations (also called flat-price correlations) and correlations of the percentage change in the corn price to the percentage change in the prices of other commodities.
  - It is important to note that when prices exhibit trends (upward or downward) over extended periods of time, the results of flat-price correlations can be spurious. Trends in the prices of several commodities occurred at times over the last decade-plus. In such cases, it is necessary to base correlations on the percentage change in prices. Both sets of correlations are shown here for reference.

- Key findings from the flat-price correlations are as follows:
  - There is a high level of correlation between corn prices and the prices of soybeans and wheat, as would be expected.
  - Correlations between corn prices and various livestock prices improve with the use of time lags. Lags up to 12 quarters are shown in Exhibit 8. Long lags were particularly relevant for analyzing prices of cattle, which have a longer production cycle.
    - For cattle, the highest correlation was 0.88, using a 12-quarter lag over the 2003-2015 time period. Notably, the percentage change correlation remained low even in this case.
    - For poultry, the highest correlation was reached using a 4-quarter lag.
    - For hogs, the highest correlation was reached using an 8-quarter lag. (Using other hog price series, peak correlations were found using a 4-quarter lag).
  - Notably, the flat-price correlation coefficients were mostly higher for the longer period studied, which predated the Renewable Fuel Standard, than they were for the post-RFS2 period.

- Using the percentage-change correlations, corn and soybeans showed a reasonable degree of linkage. However, correlations were weak across all other commodities.

Exhibit 8: Commodity Price Correlations with Corn

	2003-2015					2008-2015				
	No Lag	2 Quarter Lag	4 Quarter Lag	8 Quarter Lag	12 Quarter Lag	No Lag	2 Quarter Lag	4 Quarter Lag	8 Quarter Lag	12 Quarter Lag
Flat Price Correlations w/ Corn										
Soybeans	0.93	0.87				0.86	0.73			
Wheat	0.88	0.73				0.75	0.72			
Crude Oil	0.73	0.60				0.57	0.49			
Milk	0.56	0.55				0.33	0.38			
Shell Eggs	0.42	0.43				(0.23)	(0.10)			
Texas Panhandle Live Steer	0.49	0.56	0.65	0.84	0.88	0.05	0.16	0.31	0.69	0.66
National Lean Hog Price	0.56	0.56	0.60	0.63		0.40	0.37	0.46	0.23	
Weighted Broiler Cutout	0.65	0.69	0.76	0.70		0.33	0.48	0.70	0.53	
Percent Change Correlations w/ Corn										
Soybeans	0.72	(0.25)				0.77	(0.29)			
Wheat	0.57	(0.03)				0.68	(0.11)			
Crude Oil	0.18	(0.07)				0.33	(0.19)			
Milk	0.13	0.21				0.06	0.09			
Shell Eggs	0.10	0.10				0.02	0.17			
Texas Panhandle Live Steer	(0.03)	0.07	(0.07)	0.02	0.25	0.02	0.04	(0.14)	(0.06)	(0.28)
National Lean Hog Price	0.25	(0.01)	(0.04)	0.21		0.34	(0.07)	0.05	(0.06)	
Weighted Broiler Cutout	0.22	(0.12)	0.24	0.13		0.16	(0.14)	0.41	(0.18)	

Footnotes: Farm prices are used for corn, soybeans and wheat.

Source: Informa Economics IEG

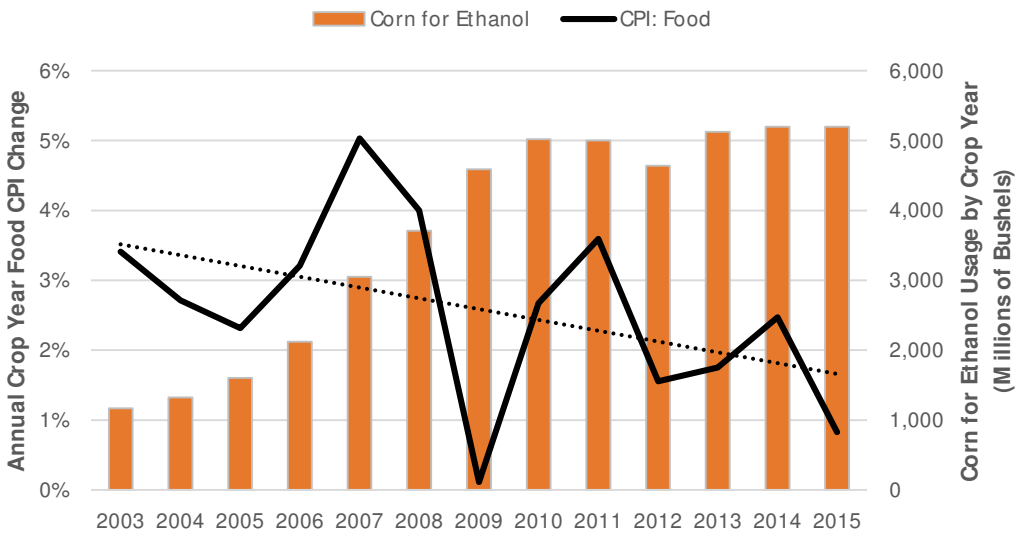
V. THE RELATIONSHIP BETWEEN CORN PRICES AND CONSUMER FOOD PRICES IN THE U.S.

WHAT IS THE RELATIONSHIP BETWEEN CORN PRICES AND FOOD PRICES?

During the years when the ethanol industry build-out was occurring, the rate of inflation in food prices decelerated. Statistical analysis indicates that changes in the corn price have had limited impact on changes in overall food prices. The complexity of the food system suggests that other factors also drive of food prices (these are examined in the subsequent chapter).

- Despite the strong increase in the amount of corn used for ethanol, the growth rate in the food CPI reported by the Bureau of Labor Statistics (BLS) slowed after passage of RFS2 at the end of calendar year 2007.
  - Analysis was conducted on a corn crop-marketing year basis (September to August). This is done since market conditions tend to be more consistent from the time one crop is harvested until the next harvest than they do within a calendar year.

Exhibit 9: Food CPI: Annual % Change and Ethanol Usage



Source: USDA, BLS, and Informa Economics IEG (analysis)

- The food CPI grew at compound average growth rate (CAGR) of 3.3% from 2003/04 to 2007/08, versus a 2.1% CAGR from 2007/08 to 2015/16.

- Corn prices were relatively volatile from 2003/04 through 2015/16, with changes in the crop-year average price ranging from a decrease of 36% to an increase of as much as 75% year-on-year. Food prices, in contrast, have been less volatile, with increases ranging from 0.1% to 5.0% over the same time period.

- Regression analysis of changes in corn price relative to the changes in the food CPI (conducted on a crop-year basis) indicate that very little of the variation in the food CPI can be explained by the variation in corn price.
  - The R^2 statistic of 0.097 implies that less than 10% of the variation in the food CPI is explained by the variation in corn prices.
  - Analysis was conducted using percentage changes in commodity prices and the food CPI due to the strong trend element in the food CPI across the time period studied, along with some degree of trend in commodity prices. As discussed previously, a strong correlation in the unmodified series may be spurious when trends are present, as an outside factor may be an important driver. Analysis using the percentage change in one variable versus the percentage change in another allows for more accurate esimates of the relationships between the data.

- More extensive correlation analysis of changes in the corn price and changes in the food CPI and its various components shows statistically weak relationships (Exhibit 10).
  - The analysis was conducted on a quarterly basis. Various lags in the corn price were examined, since raising livestock/poultry and the transformation of raw agricultural products (e.g., corn) into consumer products occurs over time.
- The analysis finds that the relationship between corn prices and food prices improves modestly when lagged multiple quarters. However, the relationship remains weak.

Exhibit 10: Correlations Between CPI measures and Corn Price

	Period	No Lag	1 Quarter Lag	2 Quarter Lag	3 Quarter Lag	4 Quarter Lag
CPI: Food	**2003-2015**	0.11	0.42	0.48	0.36	0.07
	2008-2015	0.08	0.47	0.57	0.42	(0.04)
CPI: Food At Home	**2003-2015**	0.13	0.45	0.47	0.30	0.02
	2008-2015	0.12	0.52	0.55	0.35	(0.09)
CPI: Cereals and	**2003-2015**	0.12	0.54	0.40	0.20	0.15
Bakery Products	**2008-2015**	0.18	0.54	0.54	0.55	0.29
CPI: Meats, Poultry,	**2003-2015**	(0.03)	0.22	0.43	0.15	(0.16)
Fish, and Eggs	**2008-2015**	0.06	0.35	0.40	0.50	0.18
CPI: Dairy and	**2003-2015**	0.03	0.30	0.38	0.32	(0.11)
Related Products	**2008-2015**	0.10	0.40	0.44	0.24	(0.25)

Footnotes: Using % change on % change on a quarterly basis.

Source: Informa Economics IEG

- There are several sub-components of the food-at-home CPI: cereals and bakery products; meats, poutry, fish and eggs; and dairy and related products. Among these, the strongest correlation with corn prices is with cereals and bakery products. This is due to the more direct relationship between grain and the final consumer product (e.g., corn flakes). Still, this correlation was relatively weak, at 0.54 using a one-quarter lag, which coresponds to an R^2 statistic of 0.29; this implies that changes in corn prices explained only 29% of the variation in the price of cereals and bakery products.
- The correlations between the change in the corn price and the change in the meat and dairy CPIs are weaker. Longer lags were examined for the meat CPI than are shown in Exhibit 10, in order to account for shocks that can have ripple effects over years; however, this still did not result in stonger correlations.

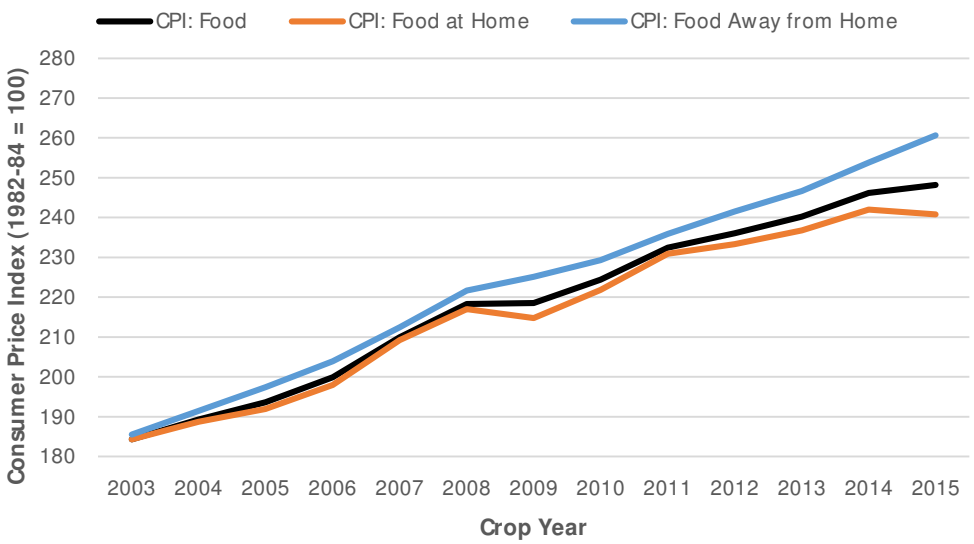
VI. DRIVERS OF U.S. FOOD PRICES

WHAT OTHER FACTORS HAVE INFLUENCED FOOD PRICES?

Food prices are highly correlated with overall inflation. Most of the growth in food prices can be attributed to increases in the core CPI (i.e., prices excluding food and energy). The remaining variation can be attributed to costs within the food supply chain and to energy costs.

- The food CPI is comprised of two main sub-indices: food consumed at home and food consumed away from home.
- The growth in the overall food CPI has been higher than the growth in the food-at-home sub-index due to the stronger growth in the food-away-from-home sub-index. Prior to the passage of RFS2, food away from home grew at a CAGR of 3.4%, versus 3.2% for food at home. After RFS2, food away from home grew at 2.6%, versus 1.8% for food at home.
- These two different measures of food prices are affected differentially by various drivers.
  - According to the food dollar series published by the USDA's Economic Research Service (ERS), farm production and inputs accounted for only roughly 19% of the 2014 food-at-home dollar. The other 81% of the food dollar was made up of post-farm-gate activities (e.g., transportation, processing, marketing).

Exhibit 11: Food-at-home CPI vs Away from Home



Source: BLS and Informa Economics IEG (analysis)

- The increase in the food-away-from-home sub-index can be attributed in part to the expansion of the foodservices share from 69.3% of the total in 2008 to 72.2% in 2014. Increases in salary and benefits accounted for the largest share of growth.

- Using the industry groups in the ERS food dollar series, Informa developed estimates of industry contribution to the growth in the food-at-home CPI.
  - The industries were grouped into three general categories: farm production and inputs; energy and transportation; and processing, retail and marketing.
  - The processing, retail and marketing component represented 71% of the food dollar in 2014 and was the largest contributor to increases in the food-at-home sub-index over time (Exhibit 13).

Exhibit 12: Composition of the Food-at-Home Dollar

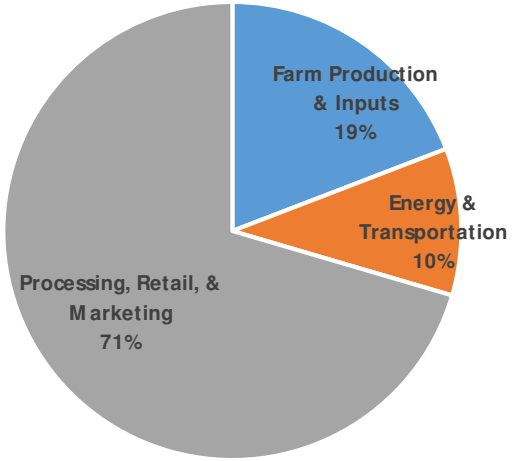
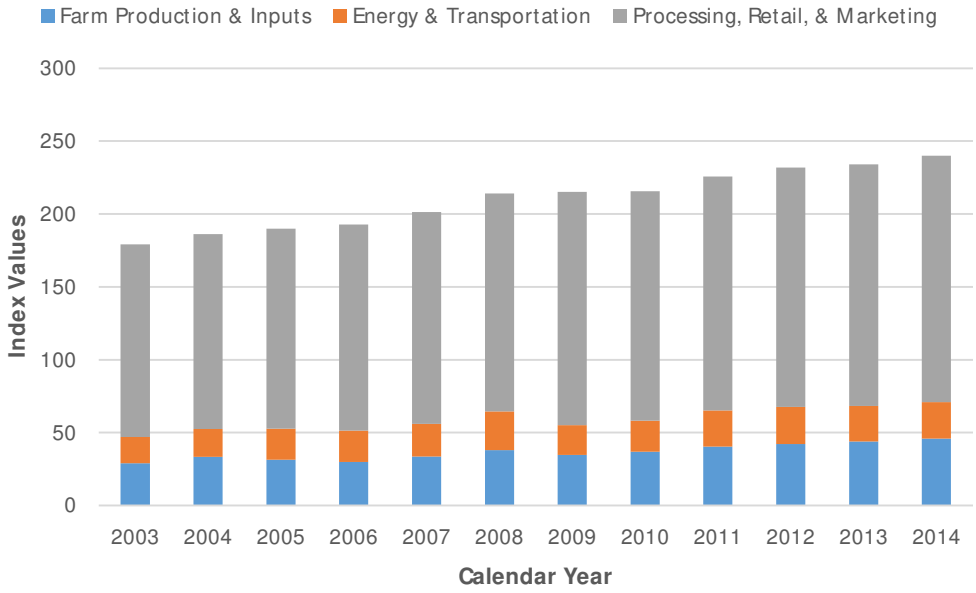


Exhibit 13: Food-at-Home Index Composition by Industry

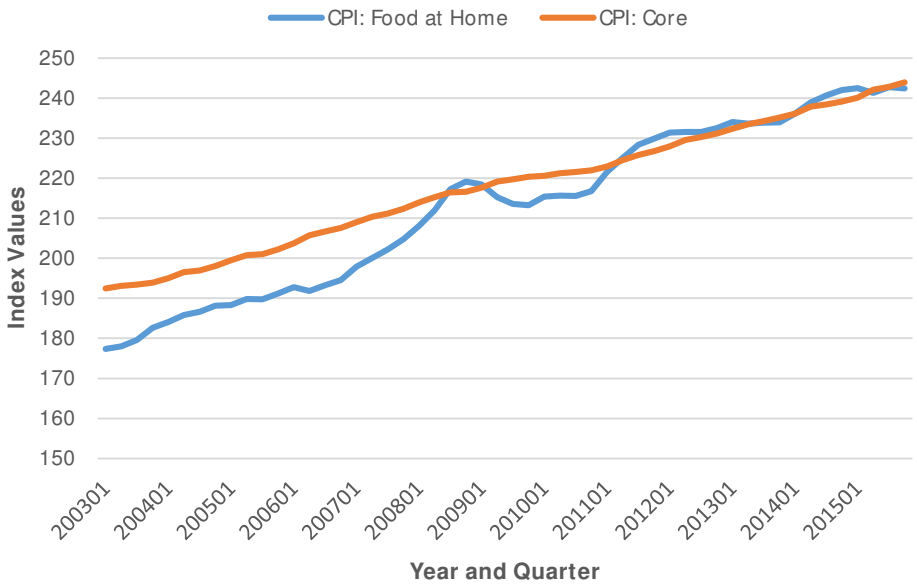


Source: ERS, BLS, and Informa Economics IEG (analysis)

- From 2003 to 2014 the food-at-home CPI grew by 61 index points. The processing, retail and marketing segment accounted for 63% of the growth, compared to 26% for farm production and inputs and 11% for energy and transportation.

- The food CPI is highly correlated with the core CPI (Exhibit 14).
  - The core CPI is a measure of inflation that excludes energy and food prices.
  - The correlation coefficient between the two is 0.98. (The resulting R^2 is 0.97.)
  - The macroeconomic factors that drive the core CPI also likely impact the food-at-home CPI.

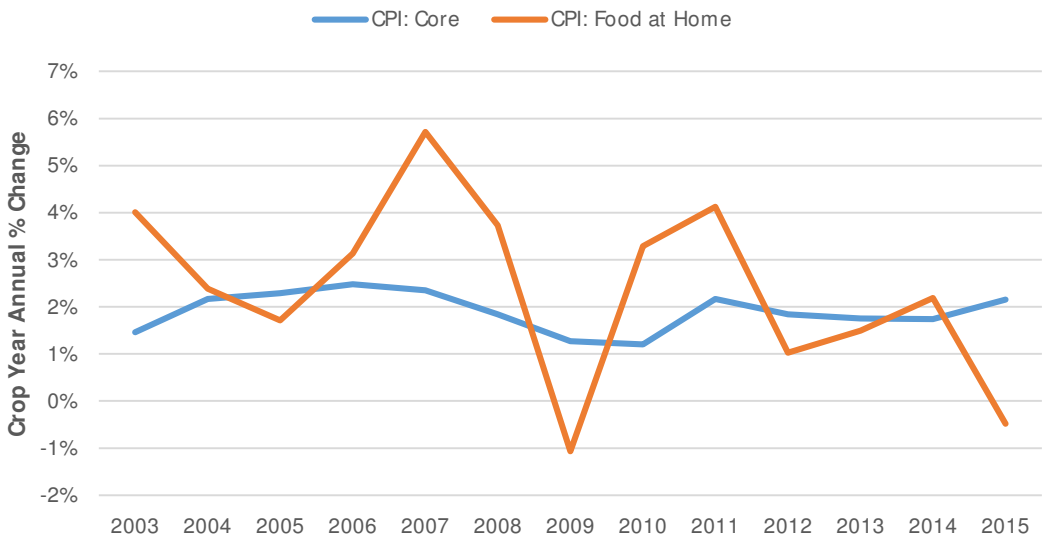
Exhibit 14: Food-at-home CPI vs Core CPI



Source: BLS, Informa Economics IEG (analysis)

- Informa analyzed the deviation between the food-at-home CPI and the core CPI (Exhibit 15). This revealed drivers of food prices other than core inflationary pressures.
  - The variables examined to explain the difference between the food-at-home CPI and the core CPI wre: the corn price, the crude oil price, and the wholesale-to-retail margin for beef. Importantly, the corn price was used as a proxy for prices of grains/row crops in general, while the crude oil price was used as a proxy for energy prices in general. The wholesale-to-retail margin was used for two reasons: meat is an important component of consumer food expenditures, and the margin acts as a proxy for transformation and marketing costs from the farm gate to the retail food level.
  - The corn price and the crude oil price both are strongly correlated to the deviation between the food-at-home CPI and the core CPI, especially when using a lag (Exhibit 16). The retail margin is found to have its strongest correlation without a lag.

Exhibit 15: Change in Food-at-home CPI vs Core CPI



Source: BLS, Informa Economics IEG (analysis)

Exhibit 16: Correlations with the Deviation in the Food-at-home CPI from Core CPI

	No Lag	1 Quarter Lag	2 Quarter Lag	3 Quarter Lag	4 Quarter Lag
Corn Price	0.73	0.81	0.84	0.82	0.76
Crude Oil Price	0.58	0.72	0.80	0.80	0.75
Beef Margin	0.75	0.74	0.69	0.65	0.63

Source: Informa Economics IEG

- Analysis indicates that 86% of the deviation in the food-at-home CPI from the core CPI can be explained using a regression with variables specified as follows: corn prices lagged two quarters, crude oil prices lagged two quarters and the wholesale-to-retail beef price spread. All of the estimated coefficients are statistically significant and positively related to the deviation (Exhibit 17).
  - A given percentage increase in the wholesale-to-retail margin had a larger impact on the in the food-at-home CPI relative to the core CPI than did the prices of corn or crude oil.
- Due to the correlation between crude oil and corn prices, Informa tested for multicollinearity in the model. Multicollinearity occurs when two predictor variables approach a linear relationship and can lead to inflated standard error estimates of the coefficients.
  - The corn price and crude oil price had a correlation of 0.73 over the period. The wholesale-to-retail margin has a weaker correlation of 0.35 with corn and 0.34 with crude.
  - Testing (using the variance inflation factor) indicated that multicollinearity was not a problem in the model.

Exhibit 17: Regression Analysis: Food-at-Home CPI Deviation from Core CPI

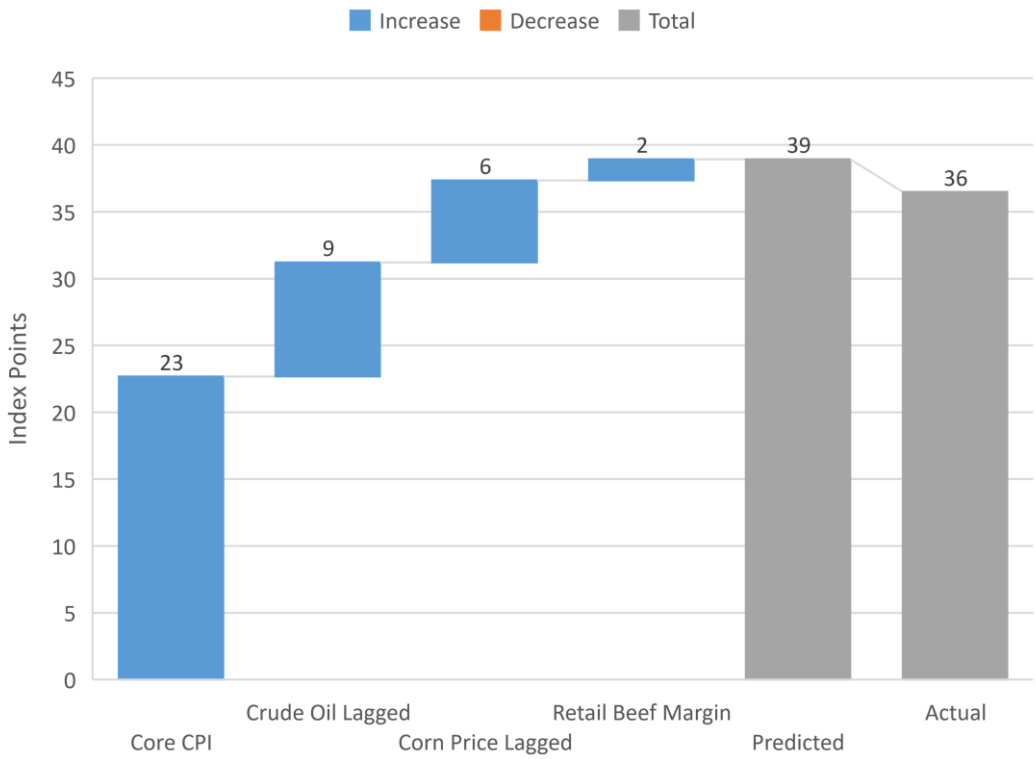
Variable	Coefficient	t Stat	Interpretation
Intercept	**-28.53**	**-13.29**	
Lagged Crude Oil Price (Proxy for Energy Prices)	**0.09**	**4.71**	**A $7/barrel* increase in crude oil price translates to a 0.63 index point increase in the food-at-home CPI relative to the core CPI**
Lagged Corn Price (Proxy for Grain/Crop Prices)	**1.51**	**5.36**	**$0.40/bushel* increase in the corn price translates to a 0.60 index point increase in the food-at-home CPI relative to the core CPI**
Wholesale-to-Retail Beef Margin (Meat Price Indicator and Proxy for Marketing Costs)	**0.06**	**5.14**	**A $20/hundredweight* increase in the margin translates to a 1.20 index point increase in the food-at-home CPI relative to the core CPI**
52 observations; R-squared of 0.86			

*equal to a 10% change in the average value during the time period

Source: Informa Economics IEG

- The impact on the food-at-home CPI attributable to changes in the core CPI and the variables examined in the regression analysis are shown for three different time periods.
  - During the first period from 2004 to 2008 (Exhibit 18), the food-at-home CPI increased by 36 index points. Of this, 23 points (two-thirds) were due to the increase in the core CPI. Based on the regression, it is estimated that 8.5 points came from a $95/barrel increase in crude oil prices, 6.1 points were from a $4/bushel increase in corn prices, and 1.6 points was from a $26/hundredweight increase in the wholesale-to-retail beef margin. In reality, the contribution of crude oil prices to the food-at-home CPI is probably modestly higher, as energy is a pervasive input throughout the U.S. economy and thus affects the core CPI.

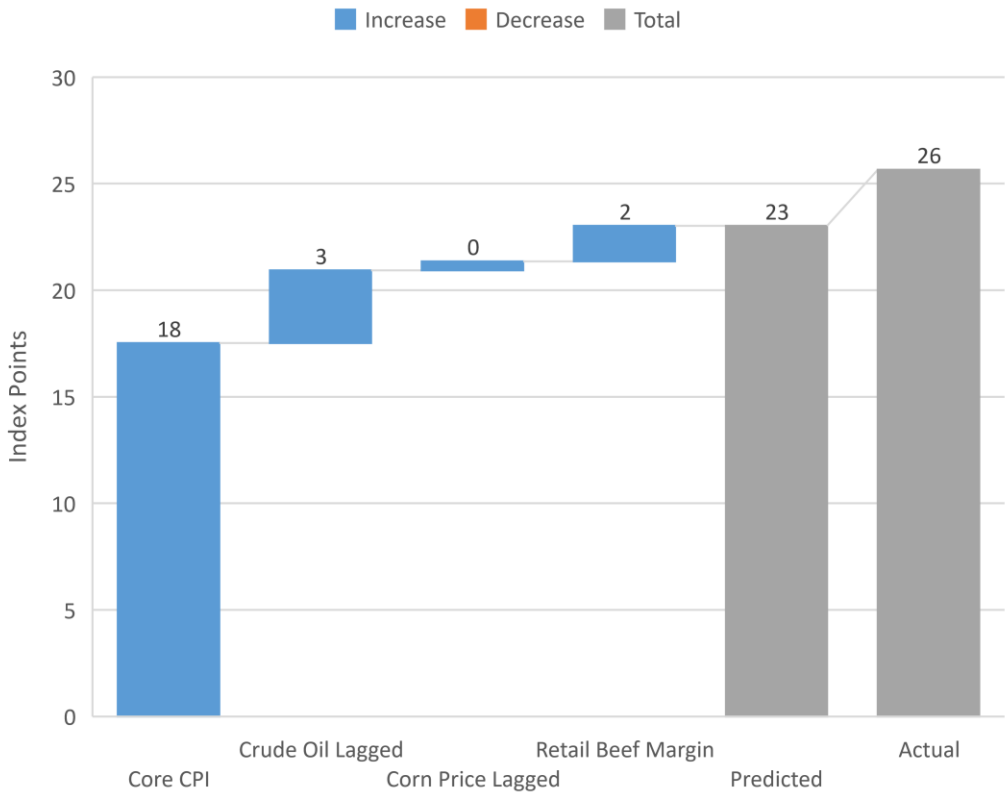
Exhibit 18: Food at Home CPI Change: Q1 2004 - Q4 2008



Source: Informa Economics IEG

- The second period examined was from the end of 2009 through the second quarter of 2014 (Exhibit 19). Adjusting for lags, this represented the period from the bottom of the price declines during the financial crisis until just before the substantial drop in crude oil prices that occurred in the second half of 2014. During this period, the food-at-home CPI increased by 26 points. Of this, 18 points were due to the increase in the core CPI. Based on the regression, it is estimated that the $38/barrel increase in crude oil prices contributed 3.4 points to the food-at-home CPI, followed by 1.7 points from the expansion of the wholesale-to-retail margin and only 0.4 points from the $0.28/bushel increase in corn prices.

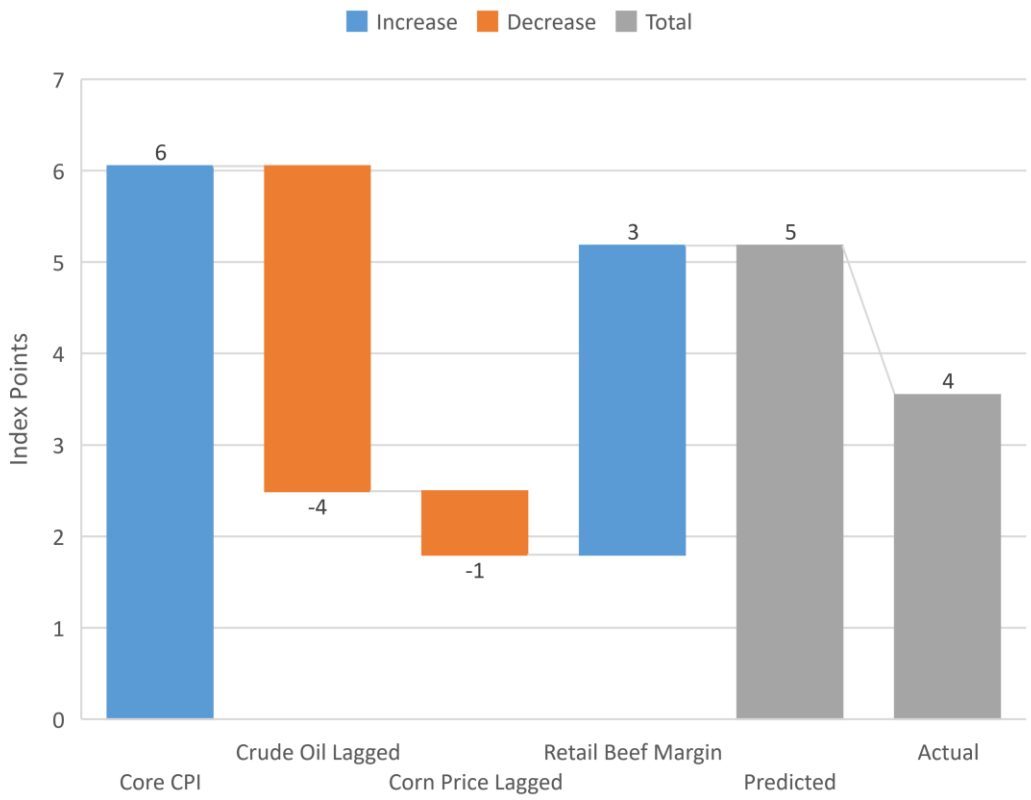
Exhibit 19: Food at Home CPI Change: Q4 2009 - Q2 2014



Source: Informa Economics IEG

- From the second quarter of 2014 to the end of 2015 (Exhibit 20) the food-at-home CPI rose despite significant drops in the prices of both crude oil and corn. These declines were more than offset by increases in the core CPI and the wholesale-to-retail beef margin.

Exhibit 20: Food at Home CPI Change: Q2 2014 - Q4 2015



Source: Informa Economics IEG

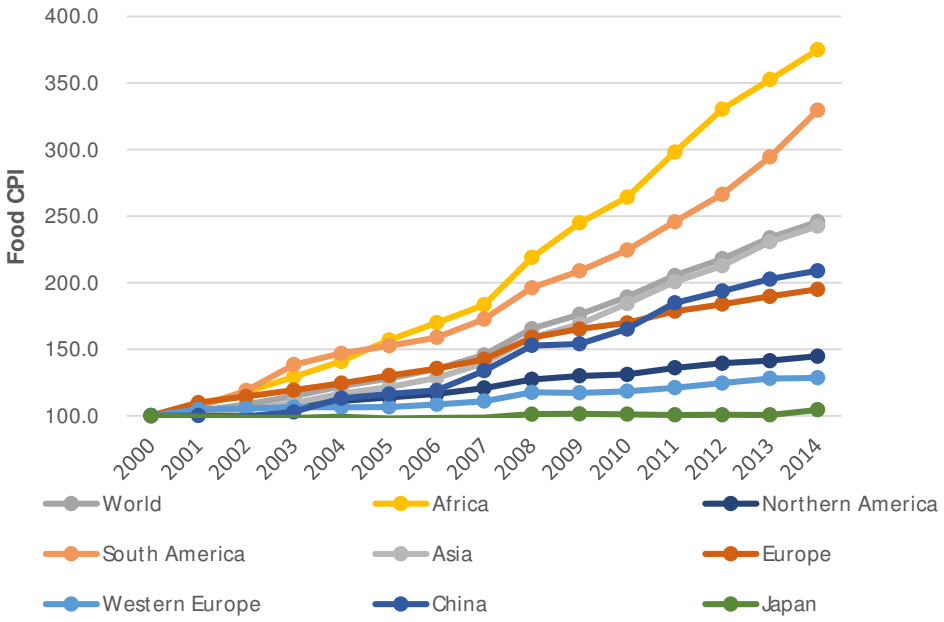
VII. THE RELATIONSHIP BETWEEN CORN PRICES AND INTERNATIONAL FOOD PRICES

WHAT PATTERNS HAVE OCCURRED IN INTERNATIONAL FOOD PRICES?

On a global basis, changes in corn prices did not have a significant impact on the food CPI overall. On a regional basis, developing countries where a higher percentage of the diet comes from basic staples experienced a larger increase in food prices over the last decade-plus than industrialized countries that consume more protein, fats and oils, and sugar.

- The Food and Agricultural Organization (FAO) of the United Nations publishes average consumer food prices at the regional level. Country-level food CPIs are calculated based on the results of household expenditure surveys (HES) and national account estimates of household consumption expenditures.[2]
- Over the 2000-2014 time period, two patterns stand out: The food CPI has increased at a greater rate in developing countries than developed ones, and the increase has continued even as ethanol production growth has slowed substantially (Exhibit 21).

Exhibit 21: Food CPI for Select Regions and Countries



Source: Food and Agricultural Organization of the United Nations

[2] http://laborsta.ilo.org/applv8/data/c7e.html

- The FAO publishes data on food security and dietary consumption in its annual Statistical Yearbook. A review of this data shows that as a country or region develops, the components of its diet shift from cereal food, fruits, vegetables and pulses to protein, fats and oils, and sugars.
  - On average, 52% of the energy intake in developing countries is in the form of cereals, versus only 31% for developed countries.
  - On the other hand, protein consumption is only 12% of energy intake, compared to 21% for developed countries. An increase in grain prices, therefore, would be expected to have a greater impact on developing countries than developed countries.
- Analysis of international food price developments was conducted over two time periods: 2003-2014 and 2008-2014. (Food CPI data for 2015 is not available at the time of this writing.) The latter reflects the time period since the establishment of RFS2.
  - The percentage change in the food CPI was compared to the percentage changes in the prices of corn and crude oil. Importantly, similar to the analysis of the U.S. food CPI, the corn price was used as a proxy for prices of grains/row crops in general, while the crude oil price was used as a proxy for energy prices in general.
  - The analysis was conducted for key regions, along with China and Japan, the two largest economies in Asia.
- The correlations between the percentage changes in the prices of corn and crude oil and the percentage change in the world food CPI were relatively weak (Exhibit 22). For corn, the correlation to the world food CPI was slightly higher for the 2008-2014 period than the longer time period. For crude oil, there was little difference between the two periods.
- The percentage change in the food CPI in developing countries and regions had a slightly higher correlation to the percentage change in the price of corn. This would be expected, since these regions tend to have a diet higher in staples, such as grains.
  - In Africa, the percentage change in corn price had a correlation of 0.57 to the percentage change in the food CPI from 2008 to 2014.
  - For China, the correlation to the change in the food CPI was 0.48. Just over half of the Chinese diet is from grains and cereals.
  - On the other hand, the food CPI in Japan had a very low correlation. Japanese diets are less than 40% grains and cereals.

Exhibit 22: Correlation of the Percentage Change in the Food CPI to the Percentage Changes in Corn and WTI Crude Oil Prices

	No Lag		1 Quarter Lag		2 Quarter Lag		3 Quarter Lag		4 Quarter Lag	
	2003-2014	2008-2014	2003-2014	2008-2014	2003-2014	2008-2014	2003-2014	2008-2014	2003-2014	2008-2014
World										
Corn	0.413	0.424	0.300	0.558	0.123	0.274	0.101	-0.069	0.080	-0.013
WTI Crude	0.281	0.352	0.324	0.290	0.133	0.034	-0.026	-0.050	-0.259	-0.248
Africa										
Corn	0.184	0.251	0.359	0.569	0.236	0.452	0.055	0.230	0.054	0.338
WTI Crude	0.295	0.315	0.286	0.274	0.136	-0.066	0.228	-0.005	0.081	0.186
South America										
Corn	0.175	0.259	0.285	0.337	0.153	0.142	-0.053	-0.188	0.040	-0.005
WTI Crude	-0.033	0.083	0.057	0.072	0.122	0.133	0.170	0.345	-0.028	0.104
Europe										
Corn	0.441	0.522	0.212	0.327	-0.126	-0.058	0.035	0.144	0.365	0.128
WTI Crude	0.120	0.093	-0.060	-0.282	0.159	-0.008	0.293	0.464	-0.027	0.145
Western Europe										
Corn	0.345	0.356	0.266	0.284	-0.060	0.110	0.046	0.314	0.383	0.204
WTI Crude	0.040	0.089	0.003	-0.106	0.237	0.201	0.303	0.448	-0.107	0.019
China										
Corn	0.150	0.333	0.399	0.482	0.278	0.142	-0.044	-0.158	-0.034	0.021
WTI Crude	0.412	0.506	0.186	0.235	-0.225	-0.215	-0.085	-0.085	-0.042	0.234
Japan										
Corn	-0.132	-0.198	0.058	0.105	0.050	-0.036	-0.069	-0.283	0.123	0.181

Source: Informa Economics IEG

Note: Highlighted correlations are those for each time period and each region that had the highest correlation. For example, the World Food CPI had the highest correlation in 2003-2014 when no lag but 2008-2014 had the highest correlation when lagged for 1 quarter.