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by

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One potential tool fertilizer dealers and producers have to protect themselves against fertilizer price risk is the fertilizer swaps market. Swaps usually settle using a floating variable price that is determined by an index of cash prices. This paper calculates hedge ratios and hedging effectiveness of urea and DAP (diammonium phosphate) swaps that settle using The Fertilizer Index with various spot price locations from the United States and internationally. Results show that urea and DAP swaps that settle using The Fertilizer Index perform poorly as a hedging tool over short time periods. As the hedging horizon increases, the hedging effectiveness of swaps improves.

Key words: fertilizer, hedging, swaps, price risk, hedge ratios, hedging effectiveness

Introduction

Fertilizer prices have been volatile since 2002 (USDA, 2016). This is particularly true in recent years, as shown by figure 1. Figure 1 shows urea price from October 2010 to March 2016. As can be seen, during this time period urea prices have reached a high of $716 per ton in April 2012 and a low of $267 per ton in early 2016.

The large swings in fertilizer prices have created much volatility in producers and fertilizer dealers' cash flows. However, participants in the fertilizer industry have limited tools to manage such risks. Traditional price risk management tools, such as futures contracts, have not been available for fertilizers except in the 1990s when the diammonium phosphate (DAP) futures contract was traded on the Chicago Board of Trade (CBOT).

One potential tool fertilizer dealers/producers can use to protect themselves against fertilizer price risk is fertilizer swaps. Like most other swaps, a fertilizer swap is a legally binding agreement where two counterparties agree to "swap" cash flows (also known as legs) based on price changes occurring at a specified period (e.g., three months). One of the legs is based on a fixed price agreed upon when the long/short enters the swap and the other leg, or cash flow, is usually based on a floating price calculated from an index of fertilizer prices. Long (short) position holders of a fertilizer swap are compensated by (pay) the amount in excess of the pre-agreed upon price if the settlement price (based on the floating price) is higher. While swaps work much like a commodity futures contract, fertilizer swaps do not involve physical delivery and are only settled financially.

Critical to a fertilizer swap is the floating price series used to calculate the cash flow and settle the gains and losses. A common index used by fertilizer swaps is The Fertilizer Index jointly published by Argus, CRU and FERTECON, three major price reporting firms in the fertilizer industry.[1] The Fertilizer Index, calculated by averaging the prices from these three firms, includes price indexes for urea, diammonium phosphate (DAP), and monoammonium phosphate (MAP) across various international locations. The Fertilizer Index is used by Freight Investor Services (FIS) to settle their fertilizer swaps that are cleared either through Chicago Mercantile Exchange (CME) or London Clearing House (LCH). First started in 2006, the FIS

[1] See http://www.thefertilizerindex.com/

fertilizer swaps have seen tremendous growth in liquidity over the past decade. While no public data are available on the total trading volume for 2016, FIS reported that the total amount of fertilizers involved in their fertilizer swaps exceeded 3.5 million metric tons for the period of March 2013-March 2014.[2]

So are fertilizer swaps an effective risk management tool for fertilizer producers and dealers? Bollman, Garcia, and Thompson (2003) found that one of the primary reasons responsible for the failure of the DAP futures contracts in the 1990s was the lack of a link between cash and futures prices created high basis risk that made futures contracts an ineffective hedging tool. Swaps could potentially reduce basis risk relative to a futures contract if the problem with the previous futures was that it was poorly designed by having multiple delivery points. While there is plenty of anecdotal evidence to suggest that basis risk remains high for the swaps contracts, there is no research to document just how large is the basis risk.

The purpose of this paper is to determine the hedging effectiveness of fertilizer swaps that are settled using The Fertilizer Index. The effectiveness of fertilizer swaps, measured as the percentage reduction in the variance of the unhedged or cash position (Ederington,1979), depends critically on how well the settlement index represents the cash price in a specific location. Weekly urea and diammonium phosphate (DAP) cash prices from various locations in the United States and across the world, as well as index prices from The Fertilizer Index are used. We find that both urea and DAP fertilizer swaps do a poor job in protecting fertilizer producers and dealers from price risk both internationally and domestic.

We are unaware of any previous studies evaluating the hedging effectiveness of fertilizer swaps. The findings of this study will provide a first look at the inefficiencies of the fertilizer swaps market and begin a discussion on improvements.

Conceptual Framework

Consider a producer placing a long hedge on a commodity using futures contracts to reduce price risk. The optimization problem to solve for the optimal hedge ratio is

$$(1) \qquad \max_{h} EU = EU(W_0 + P_s Q_s - C + hQ_f(p_f - p'_f - tc))$$

where W_0 is initial wealth, P_s is the spot price of the commodity, Q_s is the quantity of the commodity produced, C is the cost of production, h is the hedge ratio, Q_f is the futures market position, p_f is the ending futures price, p'_f is the beginning futures price, tc is futures trading costs, EU is the expected utility, and the utility function is risk averse. The producer chooses a hedge ratio to maximize expected utility of the final wealth after hedging.

[2] See http://www.freightinvestorservices.com/wp-content/uploads/2014/04/FIS-China-Urea-Presentation-April-2014_EN.pdf. In addition to FIS, CME also offers various fertilizer swaps that are settled based on prices from ICIS and Profercy. However, their trading volume is considerably lower.

The most basic hedging strategy is a naïve hedge when the hedge ratio *h*=1. For each unit of position in the cash market, the hedger would take an equal amount of the opposite position in the futures market. A producer of a commodity during the production period is considered a buyer of the commodity; therefore, the producer needs to sell futures contracts equivalent to their cash positions to hedge against price risks. When the producer sells the commodity in the cash market, they would then buy back the futures contracts. The producer would then have been perfectly hedged by using the naïve hedging strategy as long as both the cash and futures prices changed by the same amount.

Combining the work of Working (1953) with the naïve hedging strategy, Johnson (1960) applied basic portfolio theory and incorporated expected profit maximization with the risk avoidance ability of traditional hedging to derive the optimal hedging position, or hedge ratio. The optimal hedge ratio in this framework is the variance minimizing ratio.

The minimum variance hedge ratio (MVHR) is simply the covariance of the cash and futures price, divided by the variance of the futures price. The hedge ratios calculated in this paper are variance minimizing hedge ratios. This MVHR is the percentage of a fertilizer dealer or producer's spot position that should be hedged in the swaps market to minimize the variance of the hedged returns.

A weakness of MVHR is that at times it does not outperform a simple naïve hedge, but only in very price specific cases. Wang, Wu, and Yang (2015) found no consistent or significant difference between various minimum variance hedging and the naïve hedging strategy. Another more important weakness of MVHR as Lence (1996) mentions is that they may over estimate optimal hedge ratios since they do not consider costs, such as commissions, margin calls, or liquidity costs.

Myers (1991), Moschini and Myers (2002), Chan and Young (2006), and Lee and Yoder (2005) have all used various forms of a generalized autoregressive conditional heteroscedastic (GARCH) model and found that they are useful for hedging commodities. GARCH models provide for a time-varying hedge ratio instead of a constant hedge ratio. Lien, Tse, and Tsui (2002), Choudhry (2003, 2004), Harris and Shen (2003), Miffre (2004), and Yang and Allen (2005) have shown that these advanced time varying econometric models can return hedge ratios that vary drastically over time. The increased transaction costs of keeping the optimal hedge in place can reduce any benefit.

Others, such as Garbade and Silber (1983), Myers and Thompson (1989) and Ghosh (1993), consider models that account for cointegration. Kroner and Sultan (1993) developed a time varying GARCH model that incorporates cointegration as well. Lien (2004) has proven though that hedging effectiveness is minimally impacted when the cointegration relationship is not accounted for. Alexander and Barbosa (2007) found no evidence that complex econometric models provide a more efficient minimum variance hedge than a simple OLS model. Harris, Shen, and Stoja (2007) also have shown that time varying conditional MVHR models provide little improvement over unconditional MVHR models.

Methods

Following the work of Ederington (1979) and Elam and Davis (1990), week to week hedge ratios are calculated using OLS regressions. The resulting model is:

(2) $$\Delta c_t = \alpha + \beta \Delta f_t + \varepsilon_t,$$

where Δ is the difference operator, $c_t$is the log of the cash price, f_t is the log of the index price, and ε_t is an error term where $\varepsilon_t \sim iid\ N(0, \sigma_\varepsilon^2)$. The slope coefficient, β, is the hedge ratio. The resulting R-squared values are used as a hedging efficiency measure.

Hedging strategies and their effectiveness are often sensitive to the choice of hedging horizon, that is, the time interval used to measure price changes (e.g. Wang, Yu, and Wang 2015). Along with hedge ratios for week to week changes, hedging horizons of three, six, and twelve weeks will be considered. When calculating hedge ratios for longer hedging horizons, the problem of overlapping data emerges. Stefani and Tiberti (2016) show that the use of OLS on overlapping data is imprecise when calculating hedge ratios. They propose that OLS can be used on overlapping data if the robust standard errors are calculated. However, using nonoverlapping data for longer hedging horizons is not feasible in our paper due to data limitations—with only 288 weekly observations available for each price series, only 24 non-overlapping observations would be obtained for a 12 week hedging horizon. This procedure, although eliminating the autocorrelation problem, makes OLS regressions highly inefficient. By contrast, greater efficiency may be achieved with overlapping data since no information is left out in the estimation.

Harri and Brorsen (2009) argue that the use of overlapping data introduces a moving average process which must be accounted for by modifying equation (2). Following techniques used by and Kim, Brorsen, and Yoon (2015), the regression equation for the hedging horizon *k* weeks can be written as:

(3) $$\Delta C_t = \gamma + \beta \Delta F_t + \mu_t,$$

where the horizons are calculated by summing the original observations:

(4) $$\Delta C_t = \sum_{j=t-k+1}^{t} \Delta c_t,$$

(5) $$\Delta F_t = \sum_{j=t-k+1}^{t} \Delta f_t,$$

(6) $$\mu_t = \sum_{j=t-k+1}^{t} \varepsilon_t.$$

When using overlapping data, the error term in equation (6) is no longer independently distributed. This results in autocorrelation in the estimated residuals and OLS becomes inefficient and hypothesis testing is biased. To account for these problems, maximum likelihood estimation (MLE) is used to estimate hedging ratios for the hedging horizons. MLE uses a higher-order autoregressive process to approximate the moving average process. Use of an autoregressive average process has the advantage of being easier to estimate, but can also capture autocorrelation from other sources than overlapping data (Brorsen, Buck, and Koontz, 1998).

Hedging effectiveness (HE) represents the variance reduction of a hedged position over an unhedged position and is calculated by

(7) $$HE = 1 - \frac{Var(H)}{Var(UH)},$$

where *Var*(*H*) is the variance of the hedged position, and *Var*(*UH*) is the variance of the unhedged position. When using a linear OLS model, the hedging effectiveness measure is equivalent to the R^2 value. When using overlapping data, the hedging effectiveness measure must be calculated using equation (7). For this paper all reported measures of hedging effectiveness are calculated using equation (7).

Data

Data used in this paper include weekly urea and DAP cash prices from various locations in the United States and across the world, as well as the index prices from The Fertilizer Index. All data are purchased from the CRU group. Each week, CRU collects data from a wide network of market participants including producers, buyers, traders and shipping companies in each location. Price assessments reflect actual deals that are verified with both parties in the deal. Weekly data are released on Thursdays, with prices reflecting weighted averages for Friday-Thursday[3].

For urea, cash locations in the United States are the Arkansas River, New Orleans, U.S. Midwest, Great Lakes, U.S. Southern Plains, Texas Coast, U.S. South, East Coast, U.S. Northern Plains, California, and the Pacific Northwest, and for the world it includes Baltic Sea, Brazil, Central America, France, India, and the Mediterranean. The index prices we use to settle the swaps are the New Orleans for US locations and the Yuzhnyy (Black Sea), Middle East, Egypt, and China for international locations.

While the New Orleans, Egypt, and Middle East urea price indexes are formed using the price of granular urea, the Black Sea and China indexes use prices for prilled urea. Granular and prilled urea are chemically the same, but granular urea is slightly larger and harder.

For DAP, we only consider swaps that are settled in the United States. Cash locations considered include Florida, New Orleans, the eastern Midwest, the western Midwest, Southern Plains, U.S. South, California, and the Pacific Northwest. Indexes used to settle swaps are New Orleans and Tampa Indexes.

Following previous studies (e.g. Hull, 2006), differences of the natural log price, or returns are used to calculate hedge ratios. Using returns instead of price levels also eliminates the problem of spurious regressions due to nonstationarity commonly present with time series data. We conduct the augmented Dickey-Fuller test on all price levels, and find strong evidence in favor of a unit root in all price series. No unit roots are found in returns.

Descriptive statistics of urea cash prices and the New Orleans index are shown in table 1. As can be seen, fertilizer prices often do not change from week to week very often with the exception of the New Orleans price. This is not unique to our data as an unpublished private data

[3] A higher weight is placed on Thursday. The release date of the index.

set was consulted and found to show many weeks with no price changes. The Arkansas River location had the most price movement, but the price still did not change in 33 percent of the weeks. Urea prices are also higher away from New Orleans. This is expected due to the transportation costs of transporting urea up river from New Orleans. The Texas Coast price has the highest correlation with the New Orleans Index of 0.57. California and the Pacific Northwest have almost no correlation with the New Orleans Index. Descriptive statistics for international urea indexes and locations are found in table 2. The main takeaway here is that these prices change more frequently week to week than the domestic prices. This is possibly due to the price representing a larger multi-country geographic area than the domestic prices and they are not inland prices and thus less isolated.

DAP descriptive statistics for domestic location can be found in table 3. Two indexes are considered here, New Orleans and Tampa. The New Orleans DAP cash price has a high correlation with the New Orleans Index, but the Florida DAP cash price does not have a very high correlation with the Tampa Index. The Florida cash price does not change 76.5 percent of the weeks, even though the Tampa Index does not change only 19 percent of the weeks. The rest of the statistics tell the same story as urea. There is not much cash price change, prices are higher away from the index locations, and they do not have a high level of correlation with the index.

Results

Table 4 reports the optimal hedging ratio and hedging effectiveness using urea swaps settled in the United States. Outside of New Orleans, the optimal hedge ratio is never greater than 50 percent. New Orleans has a high hedging effectiveness, which is not surprising due to the index being an index of New Orleans cash prices. As we move away from New Orleans, however, hedging effectiveness declines dramatically. The cash prices in California and the Pacific Northwest essentially have zero linkage to the New Orleans index price. These two cash prices change week to week much less often than the other prices. As the hedging horizon increases though, the hedging effectiveness increases. A longer hedging horizons allows more time for the location cash price to update based off price changes in New Orleans.

Along with looking at the hedging effectiveness of urea at domestic United States locations, the hedging effectiveness of the four international urea indexes was investigated for international locations. Only locations that do not have a corresponding index are considered using a one week and six week hedge. Locations corresponding to an index have similar results of high hedging effectiveness like the domestic results for the New Orleans cash and index price. Using the Black Sea index returns the highest level of hedging effectiveness for the Mediterranean, Central America, Baltic, and Brazil. For these four locations a six week hedge provides a hedging effectiveness of over 90 percent. For France, the Black Sea, Middle East, and Egypt index provide a similar but lower hedging effectiveness for one week, while a six week hedge using the Egypt index provides a decent hedging effectiveness of 53 percent. All four indexes perform poorly for India. A reason for higher hedging effectiveness for these international locations is that the cash price series is that the cash locations represent more port locations and thus have more price movement week to week than the domestic locations price series.

The results of hedging effectiveness using New Orleans DAP index are in table 6. Like urea, the New Orleans location provides the highest hedging effectiveness. The hedging effectiveness increases as the length of the hedge increases as expected. For other locations outside of New Orleans, the index performs poorly. The results for the Tampa DAP index can be found in table 7. The Tampa index for some locations and hedging periods outperforms the New Orleans Index, but still performs poorly. The Tampa index performs poorly in Florida, which is a different finding than other indexes when compared to the cash price of the indexes location. For both Midwest locations, the hedging effectiveness is lower for a twelve week hedge than a six week hedge. This result is different than what has been found were hedging effectiveness increases as the hedging horizons increase. These results show that there is a major disconnect between the both DAP indexes and the cash price.

There currently is no DAP index for an international location. Since hedge ratios cannot be calculated for international locations hedging using an international index, correlations between international cash price series are calculated in table 8. These correlations provide an idea of if an index was created for a location, how well other location cash prices could be hedged using this created index. The North Africa and Morocco cash prices have the highest correlation. The other locations do not have a correlation higher than 0.5. It is expected that if an index for one of these international locations was created, it would have the same hedging effectiveness as has been found using the current indexes.

Conclusions

This paper has investigated the hedging effectiveness of urea and DAP fertilizer swaps that settle using The Fertilizer Index. The linkages between the price series for both domestic urea and DAP are weak and the swaps perform poorly as a hedging tool. This can most likely be attributed to the fact that the cash series in most locations have little price movement week to week. Cash prices are remaining fairly stable week to week as the index faces more price volatility. Since New Orleans is the major importing port for fertilizer in the United States, there are probably more daily transactions for fertilizer than in the interior of the country. A producer in the corn belt likely has its fertilizer price booked before planting begins and thus there could be periods when a fertilizer dealer is making no transactions due to having future sales already determined.

Internationally, urea swaps perform better but the cash price series cover more area and thus it is harder to tell if swaps are as effective in a particular region. As an example, the Mediterranean cash price cover ports all along the entire coast of the Mediterranean. So the given hedging effectiveness could be lower in Spain and higher in Lebanon. The international cash prices also consist of more port locations that see more cash price movement. These international cash prices are not as isolated due to transportation costs as domestic prices. Another factor that could influence hedging effectiveness that is not accounted for in this paper is trade barriers between country.

Further research could potentially design a strategy that entered and exited the swaps market earlier than the cash that could take advantage of the market inefficiencies. The findings of this study can further help start a discussion of potential market improvements.

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Table 1. Descriptive Statistics of Urea New Orleans Index and Domestic Cash Prices

Location	Level Mean (USD/st)	% of no weekly change	Correlation with Index
New Orleans Index	366	1.4%	-
Arkansas River	412	32.7%	0.51
New Orleans	368	4.2%	0.93
U.S. Midwest	416	43.8%	0.42
U.S. Great Lakes	422	66.9%	0.33
U.S. Southern Plains	412	30.8%	0.55
Texas Coast	414	39.5%	0.57
U.S. South	412	46.2%	0.53
U.S. East Coast	430	72.6%	0.30
U.S. Northern Plains	433	56.6%	0.43
California	461	84.0%	0.07
Pacific Northwest	468	86.8%	0.04

Source: CRU and The Fertilizer Index

Table 2. Descriptive Statistics of Urea International Indexes and Cash Prices

Location	Level Mean (USD/mt)	% of no weekly change	Correlation Black Sea Index	Correlation Middle East Index	Correlation Egypt Index	Correlation China Index
Black Sea Index	345	3.0%	-	-	-	-
Middle East Index	360	1.0%	-	-	-	-
Egypt Index	386	8.0%	-	-	-	-
China Index	343	9.0%	-	-	-	-
Mediterranean	381	12.6%	0.75	0.60	0.60	0.44
Central America	368	20.0%	0.73	0.60	0.52	0.45
Baltic Sea	337	10.2%	0.83	0.63	0.55	0.55
Brazil	365	16.8%	0.78	0.63	0.57	0.46
France	329	20.4%	0.53	0.47	0.55	0.42
India	359	82.1%	0.03	0.11	0.09	0.09

Source: CRU and The Fertilizer Index

Table 3. Descriptive Statistics of DAP New Orleans and Tampa Indexes and Domestic Cash Prices

Location	Level Mean (USD/st)	% of no weekly change	Correlation with New Orleans Index	Correlation with Tampa Index
New Orleans Index	461	0.03%	-	-
Tampa Index	455	19.0%	-	-
Florida	465	76.5%	0.37	0.41
New Orleans	461	15.3%	0.92	0.40
Midwest East	505	63.5%	0.32	0.31
Midwest West	505	62.8%	0.30	0.31
Southern Plains	502	62.1%	0.31	0.24
U.S. South	504	70.5%	0.31	0.23
California	597	96.1%	-0.5	0.06
Pacific Northwest	594	95.8%	-0.07	0.04

Source: CRU and The Fertilizer Index

Table 4. Hedge Ratios and Hedging Effectiveness of Urea Swaps – United States Locations and New Orleans Index

Location	1 Week	3 Week	6 Week	12 Week
New Orleans	1.04 (0.86)	1 (0.93)	1.01 (0.96)	1.02 (0.96)
Arkansas River	0.44 (0.26)	0.42 (0.50)	0.39 (0.55)	0.41 (0.59)
U.S. Midwest	0.36 (0.18)	0.34 (0.34)	0.43 (0.54)	0.35 (0.52)
Great Lakes	0.27 (0.11)	0.22 (0.21)	0.27 (0.35)	0.21 (0.33)
Southern Plains	0.46 (0.30)	0.45 (0.53)	0.45 (0.61)	0.46 (0.65)
Texas Coast	0.48 (0.33)	0.49 (0.54)	0.44 (0.59)	0.42 (0.61)
U.S. South	0.43 (0.28)	0.37 (0.50)	0.39 (0.56)	0.43 (0.63)
East Coast	0.22 (0.09)	0.18 (0.13)	0.15 (0.18)	0.22 (0.29)
Northern Plains	0.38 (0.18)	0.37 (0.30)	0.33 (0.39)	0.36 (0.48)
California	0.05 (<0.01)	0.04 (<0.01)	0.06 (0.04)	0.06 (0.09)
Pacific Northwest	0.03 (<0.01)	0 (-0.02)	0.01 (<-0.01)	0.03 (0.05)

Note: Equation (7) measure of hedging effectiveness in parenthesis

Table 5. Hedge Ratios and Hedging Effectiveness of Urea Swaps – International Indexes and Locations

Index	Mediterranean One Week	Mediterranean Six Week	Central America One Week	Central America Six Week	Baltic Sea One Week	Baltic Sea Six Week	Brazil One Week	Brazil Six Week	France One Week	France Six Week	India One Week	India Six Week
Black Sea	0.74 (0.55)	0.82 (0.91)	0.65 (0.53)	0.75 (0.90)	0.87 (0.68)	1.00 (0.95)	0.72 (0.61)	0.79 (0.91)	0.47 (0.27)	0.49 (0.56)	0.04 (-0.03)	0.08 (0.02)
Middle East	0.58 (0.34)	0.66 (0.78)	0.52 (0.35)	0.57 (0.77)	0.68 (0.41)	0.77 (0.81)	0.57 (0.39)	0.64 (0.80)	0.41 (0.27)	0.42 (0.53)	0.16 (-0.02)	0.23 (0.01)
Egypt	0.55 (0.35)	0.57 (0.69)	0.43 (0.26)	0.40 (0.57)	0.54 (0.29)	0.55 (0.63)	0.48 (0.31)	0.45 (0.57)	0.45 (0.28)	0.51 (0.66)	0.13 (-0.02)	0.14 (0.01)
China	0.50 (0.18)	0.55 (0.58)	0.45 (0.19)	0.45 (0.55)	0.66 (0.29)	0.66 (0.56)	0.49 (0.21)	0.45 (0.52)	0.42 (0.15)	0.41 (0.42)	0.15 (-0.02)	0.34 (0.19)

Note: Equation (7) measure of hedging effectiveness in parenthesis

Table 6. Hedge Ratios and Hedging Effectiveness of DAP Swaps – New Orleans Index

Location	1 Week	3 Week	6 Week	12 Week
New Orleans	1.02 (0.85)	1.00 (0.96)	1.00 (0.98)	1.00 (0.99)
Florida	0.28 (0.16)	0.16 (0.17)	0.24 (0.37)	0.22 (0.37)
Midwest East	0.26 (0.13)	0.21 (0.19)	0.27 (0.38)	0.23 (0.42)
Midwest West	0.26 (0.12)	0.21 (0.19)	0.25 (0.36)	0.22 (0.40)
Southern Plains	0.28 (0.10)	0.28 (0.24)	0.32 (0.45)	0.33 (0.57)
U.S. South	0.29 (0.07)	0.30 (0.26)	0.30 (0.42)	0.31 (0.53)
California	-0.04 (-0.03)	-0.05 (-0.03)	-0.07 (-0.04)	-0.04 (-0.01)
Pacific Northwest	-0.05 (-0.02)	-0.06 (-0.02)	-0.08 (-0.03)	-0.06 (-0.01)

Note: Equation (7) measure of hedging effectiveness in parenthesis

Table 7. Hedge Ratios and Hedging Effectiveness of DAP Swaps – Tampa Index

Location	1 Week	3 Week	6 Week	12 Week
New Orleans	0.61 (0.19)	0.54 (0.36)	0.67 (0.44)	0.63 (0.64)
Florida	0.43 (0.19)	0.37 (0.30)	0.43 (0.70)	0.38 (0.51)
Midwest East	0.36 (0.13)	0.34 (0.25)	0.38 (0.47)	0.33 (0.44)
Midwest West	0.37 (0.13)	0.36 (0.26)	0.38 (0.47)	0.33 (0.44)
Southern Plains	0.30 (0.06)	0.29 (0.23)	0.31 (0.41)	0.29 (0.44)
U.S. South	0.30 (0.03)	0.27 (0.23)	0.30 (0.39)	0.29 (0.45)
California	0.06 (-0.03)	0.05 (-0.01)	0.03 (0.01)	0.06 (0.09)
Pacific Northwest	0.05 (-0.03)	0.05 (-0.02)	0.03 (0.00)	0.05 (0.09)

Note: Equation (7) measure of hedging effectiveness in parenthesis

Table 8. Correlations of International DAP Prices with International Indexes

Location	Baltic/Black Seas Index	North Africa Index	Morocco Index	China Index	Jordan Index
Baltic/Black Seas	1.00	-	-	-	-
North Africa	0.47	1.00	-	-	-
Morocco	0.46	0.93	1.00	-	-
China	0.30	0.35	0.32	1.00	-
Jordan	0.02	0.11	0.17	0.09	1.00

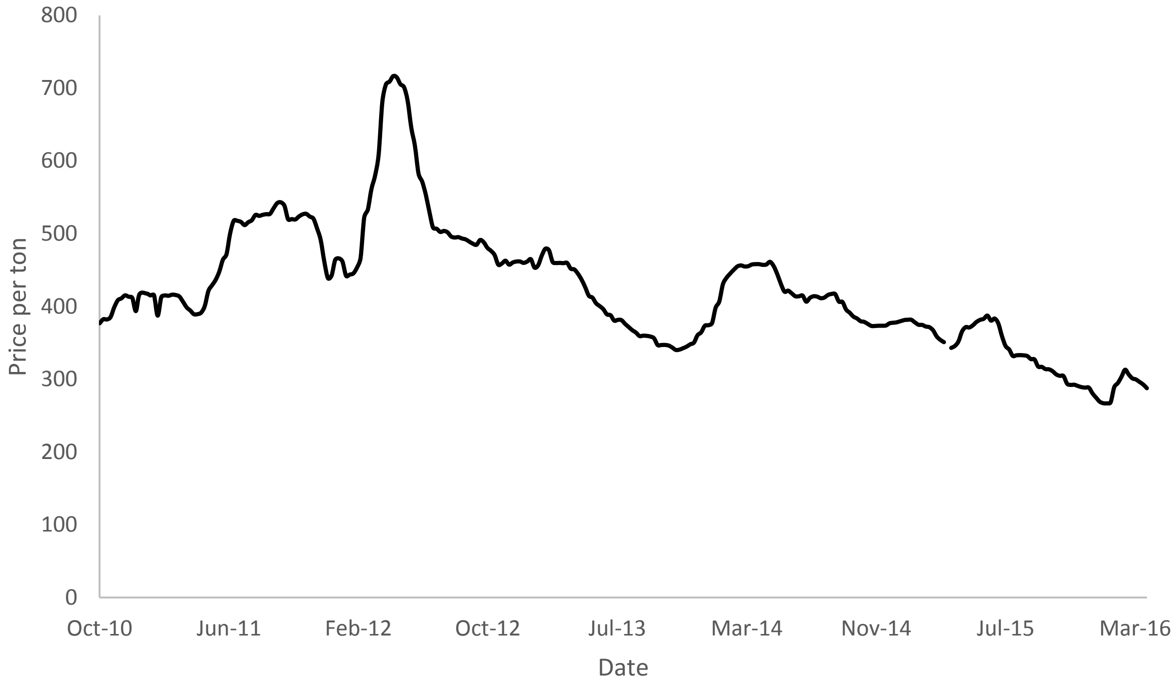

Figure 1. Price per ton of Urea, October 2010 – March 2016