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Dynamic Changes in Spatial Competition for Fertilizer

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Abstract

Changes are evolving that are impacting the U.S. nitrogen fertilizer industry. Changes in crops, increased demand, reductions in natural gas prices, and spatial competition among producers and imports are affecting the nitrogen fertilizer industry. A spatial competition model of the United States fertilizer sector was developed to determine the likely future spatial distribution of production and flows for nitrogen fertilizer. The model minimizes production and shipping costs from plants and imports to demand areas. A base model of 2010-12 was developed and a future case was modeled representative of 2018. The most valuable (lowest cost) origins for US processing are primarily in Louisiana, followed by others states with low natural gas prices. Shadow prices indicate several locations in Wyoming, Iowa, Georgia, Louisiana, Nebraska, Kansas, and North Dakota would be positive. Not all of proposed plants would be viable and if forced to operate at 75% of capacity or more only a few of the new plants including those located in Louisiana, Iowa and North Dakota would be viable.

Dynamic Changes in Spatial Competition for Fertilizer

Introduction

Major changes are evolving in the United States fertilizer sector. Traditionally this industry provided product to meet demands from both domestic production and imports from Canada and a multitude of sources primarily through the US Gulf. There are at least a couple of major factors that are resulting in the changes described below. One is the change in composition of crops within the United States, as well as the more robust commodity market, the effect of which is an increase in demand for fertilizer. Second is the dramatic reduction in natural gas prices, a primary input for fertilizer manufacturing. This change is spatially heterogeneous across regions and has a distinct impact of creating spatial advantages to plants located in lower cost natural gas states.

Third are competitive pressures. A number of new entrants are looking to enter and expand in this sector. The industry traditionally had been dominated by a few major firms which will have to confront a number of new entrants in the future. The combined impact of these exogenous factors is that there are numerous proposed new plants looking to expand or enter this sector. Indeed, as noted below there are at least 12 to 15 new plants being proposed for the United States, each at costs of about $1.5 billion or more. This industry has a number of important structural characteristics that impact competition and conduct. Specifically, domestic manufacturers have to compete with imports; demand is volatile; and firm processing functions have high fixed and low marginal costs. The combination of these ultimately means that if and as excess capacity emerges, the industry would likely evolve toward ruinous competition.

The purpose of this study is to analyze spatial competition in the United States fertilizer sector and to determine the likely future spatial distribution of production and flows for nitrogen fertilizer. A spatial competitive model is specified and solved using optimization techniques. A base case is specified and calibrated relative to 2010-2012. Changes are projected for exogenous variables to the year 2018 which is the projection period. The results indicate the likely change in distribution of production, as well as flows from production areas to county level demands. Sensitivities are used to evaluate impacts of the composition of competitors, as well as other exogenous changes. Ultimately, the paper seeks to determine the spatially competitive effects of these changes, and equilibrium production levels for proposed plants. Market boundaries are derived under different scenarios for each plant subject to these spatially dependent variables and competitive pressures.

In the first section below we provide a synopsis of the major changes occurring in this industry. Other industry and academic studies are summarized. Model specification is then described as well as data details. Results for the base case and sensitivities are then described. Finally, a summary is provided, as well as implications for the industry.

Background and Dynamic Changes

Industry Background Fertilizer is one of the important inputs that impact crop productivity. Over time fertilizer use has increased substantially, increasing from 2 t/sq km in 1961 to 11 t/sq km in 2010 (Economist 2011a and 2011b). The United States is one of the major users of fertilizer, though growth in use in other countries is accelerating. Fertilizer demand varies across crops and regionally. The most nitrogen fertilizer intensive crops are corn, potatoes and rice with moderate use in sorghum, canola, wheat, cotton and barley, while crops such as peanuts and soybeans use substantially less or nil added nitrogen fertilizer. Thus, changes in the composition of crops have an important impact on demand. Indeed, expansion of corn production in the northern plains is one of the major sources of new demand for this input.

Fertilizer use varies geographically and this has important implications for spatial competition. For example, fertilizer use for corn in recent years varied from 87 lbs/a in Pennsylvania to 178 lbs/a in Indiana. And, for hard red spring wheat it varied from 54 lbs/a in Montana to 115 lbs/a in Minnesota (USDA-ERS, 2013a and USDA-NASS, 2013b). Fertilizer use by type also varies substantially across states (AAPFCO, 2011). There are three primary types of nitrogen; anhydrous ammonia, urea and UAN (liquid).[1] There are substantial differences in demand for these types across states. Some states make extensive use of urea (e.g., New Jersey, Maine, Connecticut, Arkansas, Montana, Massachusetts, Minnesota, North Dakota, Oregon, South Dakota, Utah and Vermont), some liquid (e.g., Delaware, Arizona, Alabama, Florida, Georgia, Hawaii, Louisiana, Maryland, Michigan, Mississippi, Nebraska, Nevada, New Mexico, New York, North Carolina, Ohio, South Carolina, Texas, Virginia, Washington and Wisconsin) and others make more predominate use of anhydrous (Wyoming, North Dakota, Illinois, Iowa and Missouri). These data (in comparing 2006 and 2007, and 2011) do not suggest that fertilizer use by type changes between years, though changes in future cropping patterns and production practices may induce changes.

Traditionally this industry has been dominated by a few large players and processing was largely dominated in Oklahoma, Louisiana, Texas and a few plants scatted throughout the Midwest. In addition, the industry imported significant amounts of fertilizer to meet its needs with nitrogen fertilizer imports in the area of 57% of consumption. US Gulf imports are in the area of 13 million U.S. tons, mostly in the form of dry and ammonia primarily through Louisiana and Texas. A large amount of urea is imported through Galveston. The dominate origins of these imports were from Trinidad/Tobago, Russia, Venezuela for Ammonia, Oman, Saudi Arabia, Kuwait, Egypt, Qatar, Bahrain, and Russia for Dry, and Trinidad/Tobago, Estonia, Russia, Lithuania and Egypt for Liquid. These shipments then are distributed predominantly by rail and barge throughout the United States. Indeed shipments from the US Gulf ports to the upper Midwest are some of the dominant flows in this sector. Imports are also made from Canada. Urea is the largest volume type and import volume peaked at 1.9 mmt in 2010/11 and have since declined.

[1] In addition, other sources of nutrients include phosphorus, potassium and micronutrients. None of these are included in this study.

Imports and domestic prices are extremely volatile, and impact domestic plant utilization. Urea prices at the US Gulf have ranged from $100-200/U.S. ton in the early 2000's to a peak of over $800 in 2008 and nearly that level again in 2012, and since declined to the $300 level. Since 2007, there have been few instances in which US Gulf is less than $300 and the average from 2010 to current has been $413/U.S. ton. It is important that in contrast to price relationships within the United States, import prices seem to have little relationship to US or international natural gas prices. Also, the correlation between prices at the US Gulf and those at export origins (e.g., Trinidad, Russian black sea ports, etc.) are very low.

Fertilizer manufacturing has tremendous economies of scale. Fixed costs are high and marginal costs low, and declining with increases in output. The dominant input cost is natural gas which comprises about 50% or more of the manufacturing costs. Thus, access to low cost natural gas provides an important source of competitive advantage. Indeed, it is partly the escalation in US domestic oil output that is resulting in an increase in spatial heterogeneity in natural gas prices. Prices are lower in states such as Louisiana, Texas, Oklahoma and North Dakota. eAmmonia (2013) described the impacts of low natural gas on US production and potential impacts on exports from Trinidad. Indeed, a recent article providing an explanation for fertilizer plant location decisions indicated:

> *Those price declines have been seen across the board, even though the average commercial price still varies among states. The cost of 1,000 cubic feet of natural gas in Arizona, for instance, was $10.49 in 2007 and was down to $6.36 in 2012. Likewise, Texans paid an average of $6.76 in 2007 and last year paid $3.05. The nationwide industrial average for 1,000 cubic feet of natural gas in 2007 was $7.68 and by 2012 fell to $3.87* (Wiser, 2013).

Finally, the breadth and scope of the new entrants in this industry is important. Since about 2011 there have been many announcements for new plants. In total, about 25 new plants have been proposed throughout the United States, each proposed to produce in the area of 1.1 to 3.7 million tons/year and costing in the area of $1.5 billion or more. Characteristics of the new entrants are important.[2] Some are incumbents that are expanding (CF Industries, Agrium and Koch);[3] some are established cooperatives (e.g., CHS), or, newly-formed cooperatives (e.g., Northern Plains Nitrogen); some are regional energy firms (Dakota Gasification; Mississippi Power); and some are off-shore firms expanding into the US market (e.g., Eurochem). Aside from the structural changes giving rise to opportunities of new plants, each has differing goals. Incumbents would seek to expand and pre-empt new entrants. The cooperatives no doubt view this as a means to better serve their grower customers in a more vertically integrated system. Energy companies are looking for a use of their outputs. And, off-shore entrants are looking for opportunity, and several are looking for exports potentially to China.

[2] Greenmarkets (2014) provides a current indicator of each proposed plants status.

[3] See Leonard (2014) for a recent description of Koch in the fertilizer industry; and Kelleher (2013) for a similar interpretation of the industry evolution by CF Industries.

Previous Industry and Academic Studies There have been a number of recent industry studies that provide perspective on these emerging changes.[4] Prud'homme (2005) discussed trends and outlook for nitrogen fertilizer production, use and trade. He notes recent increases in ammonia and urea production capacity and groups urea producers into three categories 1) producers serving maturing domestic markets (accounting for 28% of supply), 2) export oriented producers (16% of supply), and 3) emerging producers catering to domestic markets (56% of supply). Prud'homme indicated that the export producers and emerging producers are likely to be able to expand capacity, with export producers taking advantage of large cost-competitive reserves of natural gas.

Yara (Yara 2010 and 2012) provides a detailed description of the underlying demand, pricing and costs for nitrogen fertilizer. Debertin (2012) and Lamp (2013) explained the logic of the proposed plant to be built by CHS. A recent presentation by CF Industries outlook (Kelleher 2013) indicated returns to their new plants ranged from 14-20% depending on natural gas and urea prices. The World Bank (2013) pointed to the easing of world fertilizer prices in part due to the expansion of production in regions with lower natural gas prices (p. 12).

There have been a few studies on the fertilizer industry and logistics and fewer academic or public studies on this industry. Huang (2007) analyzed the impacts of rising natural gas prices (at that time) on fertilizer price and described the structure of the industry and geography of production. Cassavant et al., (2010) reviews the fertilizer industry and the importance of transportation. They indicate issues facing the U.S. fertilizer industry include volatility of US fertilizer prices, transportation policies and long-term increases in fertilizer use.

Zilberman et al (2013) analyzed the future demand for food and point to the need for increased fertilizer requirements. For varying reasons it is important to have a better understanding of factors influencing future fertilizer nutrient requirements and availability. Rosas (2011) developed model of world fertilizer demand, tied into the world FAPRI projections model. Olson, Rahm and Swanson (2010) examined factors affecting plant input supply industries. They indicate that for the fertilizer industry, important market forces include effect of high fixed costs, market segmentation, the presence of low cost natural gas supplies, etc. Key producers and exporters of nitrogen have low cost natural gas such as the Mideast, Russia and Caribbean Basin. Global industry concentration for nitrogen producers remains low with Herfindahl-Herschman Index scores of less than 400. They indicate that capacity of U.S. production of nitrogen is down about 40% from 15 years ago due largely to increased competition from foreign producers and high U.S. natural gas prices. Recent decreases in natural gas prices due to development of shale gas reserves have potential to slow or reverse this trend.

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[4] In addition to these, there are many non-public industry studies on pricing (e.g. Green Markets, International Fertilizer Industry Association (IFA)) and industry developments. However, these are typically only available with subscriptions and as such are note reviewed here.

Model Specification

Overview The analytical framework developed in this study is a spatial network flow model of the U.S. fertilizer industry. The model is calibrated and used to analyze production, imports, and fertilizer flows from origins to destinations. Primary activities include producing nitrogen fertilizer in existing and proposed plants, importing fertilizer and shipping from origins to demand. Costs are derived for each of these activities. Fertilizer plants are at actual locations and locations for proposed new plants. Imports are through the US Gulf (Louisiana and Texas) and from Canada. Demand is modeled at the county level. And, each activity is modeled for the 3 types of nitrogen fertilizer, anhydrous ammonia, dry (urea) and liquid (UAN).

Demand is determined at the county level for each crop and then aggregated by type of fertilizer. The model includes production at 29 existing plants, and 11 proposed new plants or plant expansions. Each produces different types of fertilizer and has capacity restrictions for each. Imports from Canada are modeled similar to US production. Imports of fertilizer by type at the US Gulf is based on import prices, and shipping costs to destinations.

The model is calibrated and solved for the base case period which is 2010-2012. Projections are made for the important exogenous variables to the year 2018. These are used as values in the model to derive the spatial equilibrium for 2018. Comparisons are then made to outputs of interest between the base case and projection period. The variables of particular interest are demand, production of fertilizer by type at each plant, imports and shipments by model from origins to destinations.

Objective Function The model specified is based on spatial competition and network flows. It uses linear programing that is integrated with a GIS data structure. Figure 1 provides a description of the major features of the model. The mathematical model derives the least cost of procurement and shipping for nitrogen fertilizers to meet US demands by county by type specified as:

$$Min\ Cost = \Big[\Big(\sum_{q,p,T,M} X5_{q,p,T,M} + \sum_{q,j,T,M} X1_{q,j,T,M}\Big) * CostIm_T + \sum_{r,s,T,M} X6_{r,s,T,M} * CostCim_{r,T} + \Big(\sum_{i,j,T,M} X4_{i,j,T,M} + \sum_{i,p,T,M} X7_{i,p,T,M}\Big) * CostUS_{i,T}\Big] + \Big[\sum_{q,p,T,M} X5_{q,p,T,M} * \big(CostBrg_{q,p,M} + CostBrgT\big) + \sum_{i,p,T,M} X7_{i,p,T,M} * \big(CostBrg_{i,p,M} + CostBrgT\big) + \sum_{r,s,T,M} X6_{r,s,T,M} * CostShip_{r,s,T,M} + \sum_{s,j,T,M} X3_{s,j,T,M} * CostShip_{s,j,T,M} + \sum_{q,j,T,M} X1_{q,j,T,M} * CostShip_{q,j,T,M} + \sum_{p,j,T,M} X2_{p,j,T,M} * CostShip_{p,j,T,M} + \sum_{i,j,T,M} X4_{i,j,T,M} * CostShip_{i,j,T,M}\Big] \quad (1)$$

S.T.

$$\Big(\sum_{i,T}\sum_{j,M} X4_{i,j,T,M} + \sum_{i,T}\sum_{p,M} X7_{i,p,T,M}\Big) \le USCap_{i,T} \quad (2)$$

$$\sum_{r,T}\sum_{s,M} X6_{r,s,T,M} \le CanCap_{r,T} \quad (3)$$

$$\sum_{s,T,M}\sum_{r} X6_{r,s,T,M} = \sum_{s,T,M}\sum_{j} X3_{s,j,T,M} \quad (4)$$

$$\sum_{r,s,T,M} X6_{r,s,T,M} \leq ImportsCanada2012_T \quad (5)$$

$$\left(\sum_{q,p,T,M} X5_{q,p,T,M} + \sum_{q,j,T,M} X1_{q,j,T,M} \right) \leq ImportsGulf2012_T \quad (6)$$

$$\left(\sum_{p,T,M} \sum_{q} X5_{q,p,T,M} + \sum_{p,T,M} \sum_{i} X7_{i,p,T,M}\right) = \sum_{p,T,M} \sum_{j} X2_{p,j,T,M} \quad (7)$$

$$\left(\sum_{j,T} \sum_{s,M} X3_{s,j,T,M} + \sum_{j,T} \sum_{q,M} X1_{q,j,T,M} + \sum_{j,T} \sum_{p,M} X2_{p,j,T,M} + \sum_{j,T} \sum_{i,M} X4_{i,j,T,M}\right) = Demand_{j,T} \quad (8)$$

$$\sum_{i,T \in i,T} \sum_{j,M \in j,M} X4_{i,j,T,M} \geq 0.1 * USCap_{i,T} \quad (9)$$

$$\sum_{j,T,M \in j,T,M} X1_{Galveston,j,Dry,Rail} \leq Rail2012 \quad (10)$$

$$\sum_{p,T,M \in p,T,M} X2_{p,MNBarge,T,M} \leq MNBarge \quad (11)$$

Where sets included:

T= Type of fertilizer namely: Anhydrous, Urea and Liquid,

M=Mode of transportation, namely: Rail, Truck, and Barge,

i=US Plant Locations,

j= County Level Demand Points,

p=Inland Trans-shipment Locations for Barge,

q=Gulf Import Port Locations,

r=Canadian Plant Locations,

s=Canada/USA cross-border Points,

Shipment flows were:

$X1_{q,j,T,M}$=shipments of nitrogen fertilizer by type T from Gulf Import locations q to Demand j by mode (Rail or Truck),

$X2_{p,j,T,M}$ = shipments of nitrogen fertilizer by type T from Inland Trans-Shipment Locations p to Demand j by mode (Rail or Truck),

$X3_{s,j,T,M}$= shipments of nitrogen fertilizer by type T from Canada/USA cross-border points s to Demand j by mode (Rail or Truck),

$X4_{i,j,T,M}$=shipments of nitrogen fertilizer by type T from U.S. Plants i to Demand j by mode (Rail or Truck),

$X5_{q,p,T,M}$=Barge shipments of nitrogen fertilizer by type T from Gulf Import Locations q to Inland Trans-Shipment Locations p by mode (barge),

$X6_{r,s,T,M}$=shipments of nitrogen fertilizer by type T from Canadian Plant Locations r to Canada/USA cross-border points s by mode (Rail or Truck),

$X7_{i,p,T,M}$=shipments of nitrogen fertilizer by type T from Louisiana Plants only to Inland Trans-Shipment Locations p by mode (Barge),

$CostIm_T$=Cost of procuring imports at Gulf port locations by type *T,*

$CostCim_{r,T}$=Cost of procurement at Canadian plant *r* by type *T,*

$CostUS_{i,T}$= Cost of Procurement at USA Plant *i* by type *T,*

$CostBrg_p$=Cost of shipping by mode (barge only) to inland trans-shipment point *p*,

CostBrgT=Cost of unloading from barge and transfer cost,

CostShip= cost of shipping by mode *M*(truck, rail), by type *T* for each pair of origins*(i,p,q)*-destinations *(j),*

$USCap_{i,T}$=USA capacity at plant *i* by type *T,*

CanCap= Canada capacity at plant *r* by type *T,*

$ImportsCanada2012_T$= imports from Canada to USA in year 2012 by type *T,*

$ImportsGulf2012_T$= US-gulf imports in year 2012 by type *T,*

$Demand_{j,T}$=Demand at county *j* by type *T,*

Rail2012= rail capacity constraint for Galveston, TX dry fertilizer shipments less than flow of 2012, and

MNBarge= maximum allowed shipments via barge to Minnesota.

The first element of the objective function represents the cost of procurement of imports at the US Gulf, from Canada, and US plant production. The second major element represents shipping costs by type and mode. Constraints include equation 2 and 3 which force shipments out of each plant to be less than capacity in the United States and Canada respectively. Equation 4, is a balance equation which forces shipments out of Canadian plants to cross-border points to equal shipments from cross-border to US county demand points. Equation 5 limits total Canadian imports by type to be less than Canadian imports in 2012. Equation 6, limits total US-Gulf imports to be less than average total imports at US-gulf from 2010-2012. Equation 7 is a balance equation that limits the sum of imports from ports to inland transshipments points and US plants with barge access to equal total shipments that flow out of inland-transshipment points. Equation 8 is a balance equation were the sum of shipments from Canada-US cross border points, from US-Gulf imports direct, from inland transshipment points, and from US-plants direct, have to equal total demand at county by type. Equation 9 forces US plants to operate at a minimum of 10 percent of annual plant capacity. Equation 10 forces rail movements for Dry imports from Galveston to be less than those observed in 2012 and Equation 11 imposes a maximum on nitrogen fertilizer shipments via barge to the Minnesota Barge inland transshipment point due to open river limitations.

The model was specified and solved in SAS. Data were then exported and displayed in GIS.

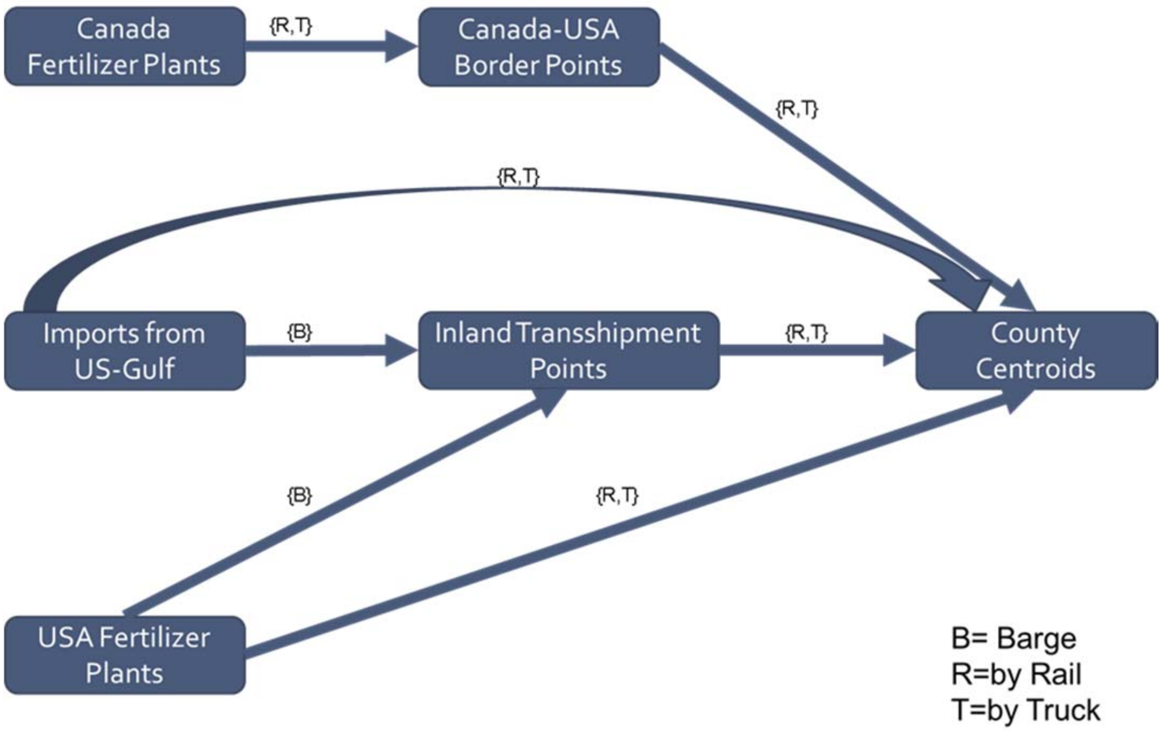

Figure 1. Graphical Depiction of Nitrogen Fertilizer Flow Model by Transportation Mode (Barge, Truck, Rail).

Data and Derivations

Data sources and transformations are described in this section. There are a number of critical variables used in the model which are described in this section. These include the demand for fertilizer, import prices and volumes, plant locations and capacities by fertilizer type, and processing costs.

Fertilizer Demand County level demand for fertilizer was derived using data on nitrogen use by crop type and acres planted. Acres planted were for barley, canola, corn, cotton, peanuts, rice, sorghum, soybeans, wheat (treated separately for hard red spring, durum and hard red winter) and potatoes for 2010-1012 (USDA-NASS, 2013a). Nitrogen use by crop type was obtained from USDA-ERS, 2013a and USDA-NASS, 2013b on a state level basis and applied to all counties within the state. Total demand for nitrogen by type (Anhydrous, Dry (Urea), Liquid (UAN)) was obtained by taking county level demands and multiplying these with the proportion of state level demands by type (AAPFCO, 2011).

Forecasted demand for 2018 was estimated by assuming planted acres by crop within a county increase by the average annual rate of change for planted acres from 2000-2012. These were used to estimate the change in planted acres from 2012 to

2018. Percentages of acres planted to each crop were derived. These were then applied to total county acres in 2012 to reflect changes in crop mix rather than planted area expansions. The recent expansion of corn and soybean acres in the 2000's were reflected in large increases in total planted acres in selected counties. To reduce this explosive effect, it was assumed total planted acres would be unchanged and acreage would reflect shifts from one to the other based on proposed percentages of each crop, rather than expansions in area planted. The new acres were multiplied by nitrogen use by crop which was also increased to reflect increased use for higher yields to obtain total nitrogen demand by county. These were again converted to demand by type, by applying state level proportions for anhydrous, dry and liquid to county level nitrogen demand (AAPFCO, 2011).

The results from this procedure indicate the 2018 demand to increase by 4.7% from the 2010-12 base case. This would be comprised partly due to the impact of greater yields (2%), and partly due to the shift in the composition of area planted (2.7%). The change in demand by type will vary. These results suggest a 5.6% increase in anhydrous, 5.5% increase in dry and 3.8% increase in liquid (See Figure 2). The states with the largest increases are: anhydrous: IL, IA, MN, ND; dry: AR, MN, ND, SD and liquid: IL, IN., IA, NE, OH. These differences are due to state level preferences of fertilizer by type; and there is there is no evidence of changes in preferred N type in these data.

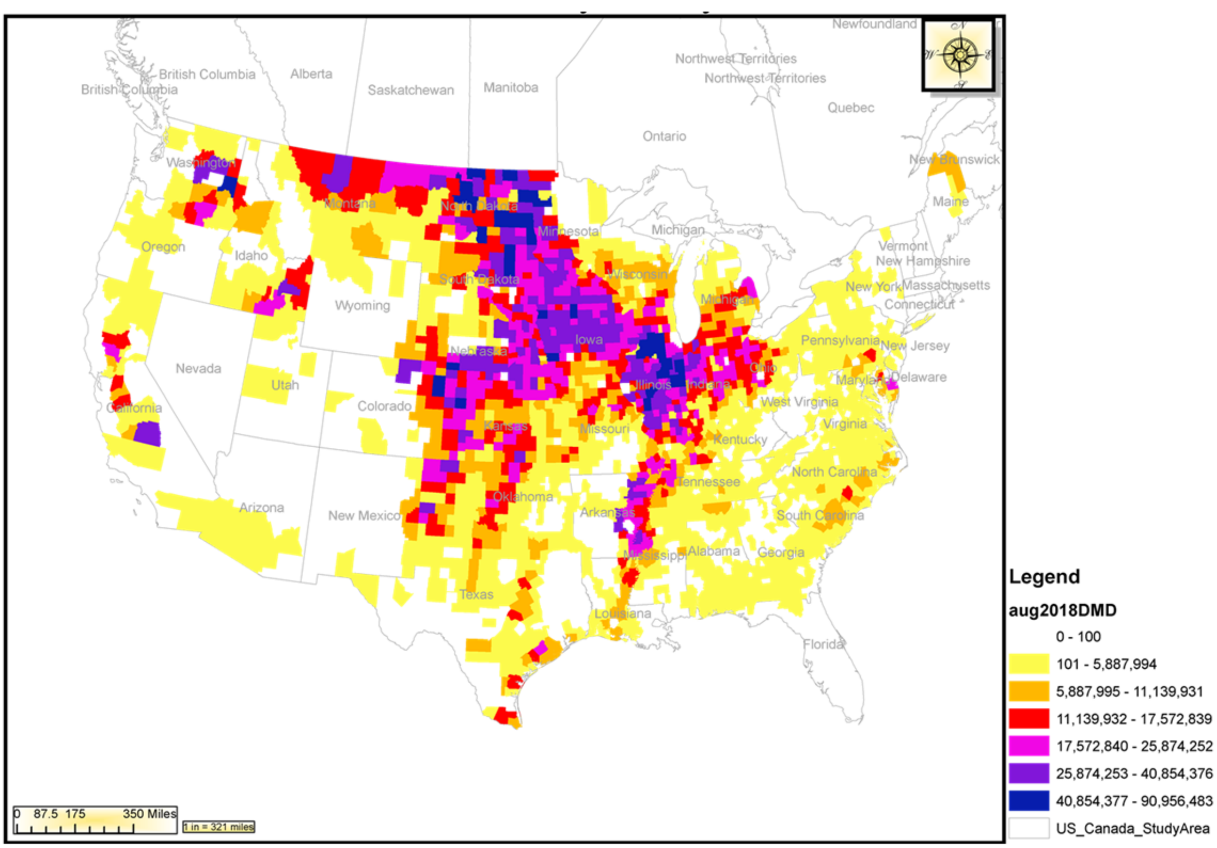

Figure 2. Nitrogen Fertilizer Demand by County, 2018.

Imports Import volumes from Canada to the U.S. were from Statistics Canada, 2013. These were averaged for 2010/11 to 2011/12 and used as constraint for maximum Canadian imports. Imports for US ports were aggregated to US Gulf and are from USDA-ERS, 2013b. Prices were obtained for these values from Bloomberg and Greenmarkets.

Fertilizer Plants Capacities and Costs Plant capacities were obtained from IFDC, 2013. These list capacity by type (Anhydrous Ammonia, Urea, and Nitrogen Solutions). Data on new or prospective plants were obtained from IFDC, 2013, *Agweek*, from press releases, Greenmarkets, and other industry sources.

Costs of production by product were derived from those estimated by Maung, Ripplinger, McKee and Saxowsky, 2012. Specifically, the costs represented in that study which reflect the economies and input requirements for modern state of art plants, were re-engineered to develop costs functions for fertilizer manufacturing. Costs for anhydrous, dry and liquid were estimated as a function of costs of natural gas, electricity, other costs and total capacity to reflect economies of size.

Costs for natural gas by state were taken from EIA (2013a) and were the average of monthly industrial prices from Jul 2010 to Feb 2013. The natural gas spread for each state was estimated as the spread between industrial prices and Henry Hub Futures for the current 2010-2012 case and for the future case. Spatial basis levels were assumed unchanged, while Henry Hub prices were reflective of current estimates for 2018 Henry Hub prices. Electricity costs were also obtained by state from EIA (2013b) and reflect average cents/kw hour from for 2010-2012.

Costs for anhydrous ammonia were assumed to be a function of cost of natural gas, electricity, O&M, Capital Costs following Maung et al. (2012), where:

$\text{NGas Cost}_i = 33\ \text{MMBtu/ton}*(\text{NG Spread}_i+\text{HH})*\text{Capacity}_i$

$\text{Elect Cost}_i = (1919-119.16*\text{Ln}(\text{Capacity}_i)*\text{Capacity}_i*\text{Elec Price}_i/100$

$\text{O\&M Cost}_i = (40.023-.000007*\text{Capacity}_i)*\text{Capacity}_i$

$$Capital\ Cost_i = \frac{(121053 * Capacity_i^{.6505})}{\sum_{n=1}^{N} \frac{1}{(1+i)^n}}$$

$\text{Anhydrous Cost}_i = \text{NGas Cost}_i + \text{Elect Cost}_i + \text{O\&M Cost}_i + \text{Capital Cost}_i$

Costs for Urea were derived from Anhydrous Cost where:

$\text{Urea Cost}_i = (\text{Anhydrous Cost}_i*.58) + (\text{NG Spread}_i+\text{HH})*5.166667+22$

Costs for UAN were estimated as a function of Urea costs where:

$\text{UAN Cost}_i = (-1242.3+257.15*\ln(\text{Urea Cost}_i))$

The processing costs included operating, capital, natural gas and electricity.

The base case used these input values for each state for the period 2010-12 and the projected period used EIA estimates for the period 2018 by state based on HH and the state level differential relative to the projected HH value. These costs were then included as inputs into a re-engineered analytical model (i.e. from above) and ultimately used to derive cost for each individual plant. These are shown Figure 3. Important are the obvious economies of size and the variability across products. The variability across plants is largely due to natural gas and electricity prices, location, and size.

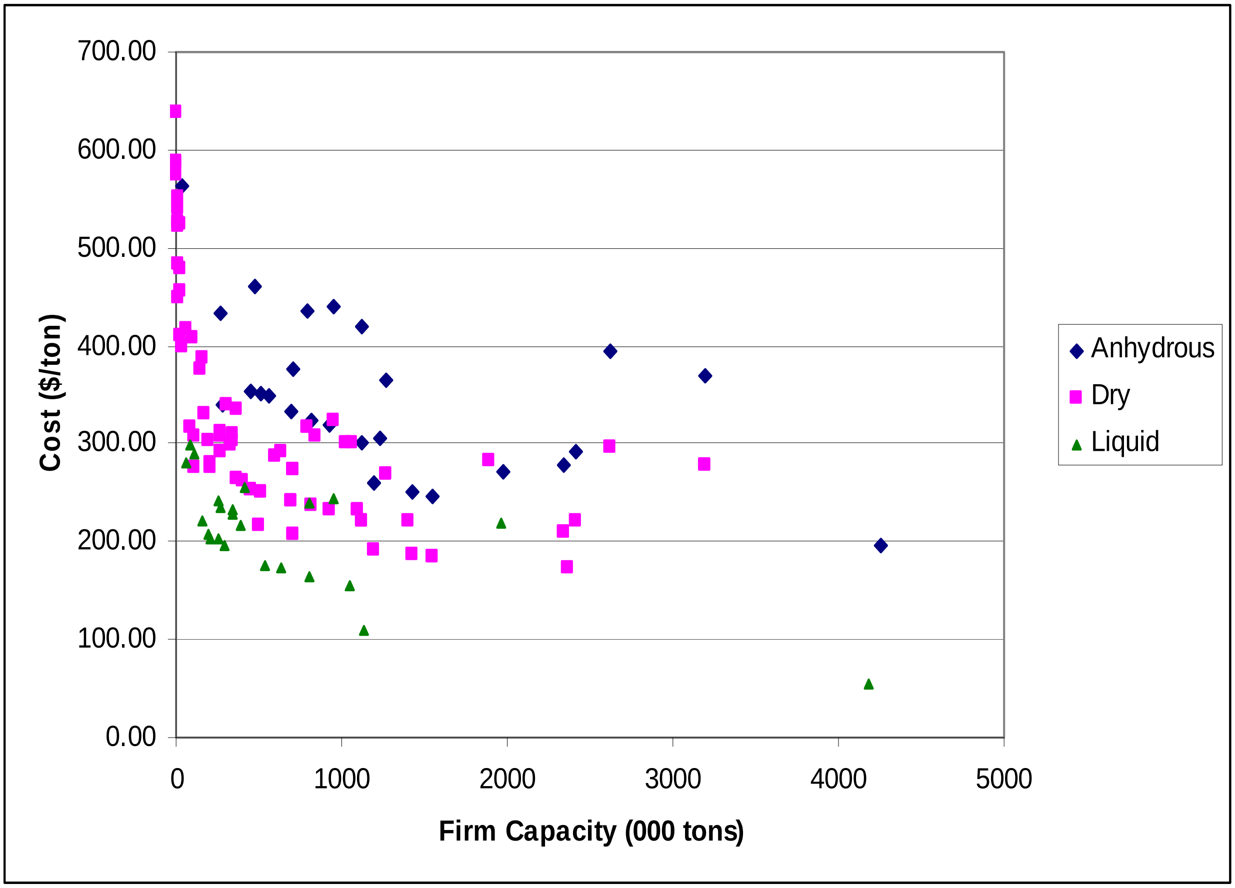

Figure 3. Estimated Production Cost by Type and Firm Capacity.

Shipping Costs Shipping costs were derived and/or estimated from each origin to the county destination for each of rail and truck and combinations of shipments with barge. Costs were estimated by type (anhydrous, dry and liquid).

Rail costs were derived and estimated on mileage based relationships from current mileage based tariffs for rail (BNSF, 2013abc). These were reviewed by industry participants to identify some shipments which deviated substantially from rates depicted in these functions. In these cases, the rates suggested by industry were used.

Truck rates were collected from 3 major firms and were based on mileage and truck capacity. These were derived for each firm and the average across the three firms quotes were used. Barge rates were used for northbound shipments by barge and the data was from River Transport News (2013).

Scope of Model and Assumptions A detailed spatial competition model was developed and solved using optimization techniques and extracting results in GIS. The model included the most important spatially dependent supply chain costs. These include processing costs for each individual fertilizer plant; shipping costs of products by rail, truck and/or barge/truck or barge rail combinations. Imports were modeled endogenously for Canadian produced products, and for import products through the US Gulf.

The base case included a number of assumptions. The base case was specified to be reflective of the market conditions in the period 2010-2012. One of these was the value used for US Gulf imports. These were taken from world market price data (extracted from Bloomberg) and were the average over this period. The results were reviewed with industry representatives, and a number of assumptions or restrictions were imposed to calibrate the model to reflect market flows and operations in recent years.

The projection period was for 2018. Assumptions for this period are described briefly. Demand projections were made at the county level as described above. Processing costs were determined for each individual plant and were adjusted to reflect the 2018 EIA projections for HH NG values. These were then adjusted for each individual state using current state level differentials from EIA relative to HH. All announced plants were allowed to operate. Finally, US Gulf import values were assumed and specified as the most current values for these markets. These values were $440, $290 and $230/ton for anhydrous, urea and liquid respectively. These values were chosen after careful review of values over time, and processing costs in competing countries, as well as predominate fertilizes/NG relationships. Review of historical data and relationships indicate these values are near the bottom range of values, though there is a high degree of volatility.

Upon reflection, these assumptions may be interpreted as being probably conservative. These assume a relatively conservative, though defendable, approach to demand changes, all new plants are developed, and US Gulf values go to traditionally extremely low values.

Results

Results are shown and compared below for the base case and the 2018 projections, each reflective of the above. The purpose of the base case is partly to calibrate the model so that it conforms generally to what are expected to be current flows. The 2018 provides results that would likely occur under the projection period and subject to the assumptions above. Then, results from a number of sensitivities are presented.

Base Case and 2018 Projections The base case calibrated well with industry expectations, particularly regarding plant level production, imports and flows[5]. Flows by type of fertilizer were derived and for the base case are summarized. Each type of fertilizer has large volume flows from the US Gulf to the Midwest and to the Upper Midwest. Canadian imports cross the border in Manitoba, Saskatchewan and Alberta and are largely distributed in the upper Midwest. All of these flows are supplemented by shipments from incumbent local processors. These are generally from plants shipping northerly to the deficit regions. Large domestic origins for anhydrous are from each of the major producing regions, particularly Oklahoma and others. Urea shipments include large volumes from Galveston to the Upper Midwest, in addition to US Gulf and Louisiana origins on barge and barge-rail over St Louis and the Upper Mississippi. Liquid shipments in the base case are dominated by imports from Canada and the US Gulf, and shipments predominately from domestic processors in Oklahoma, and Iowa.

Changes in the US fertilizer industry described above ultimately results in major changes in the supply and demand for capacity. These are summarized below on the assumption that all of the currently proposed plants are adopted, though they would only produce if and as they are competitive relative to the spatial market conditions (Table 1). The results suggest demand will increase by 5.6%, 5.5% and 3.8% respectively for anhydrous, urea and liquid. Domestic capacity will increase substantially, by 49%, 92% and 57% respectively for anhydrous, urea and liquid. Finally, in our 2018 model as inferred here, imports at the U.S. Gulf were nil, however, Canadian imports for anhydrous and liquid declined slightly, while dry imports increased by 700,000 tons. Of course, all these plants will not be developed nor will the new entrants operate at capacity, but, these give an indication of the changes confronting this market. In our 2018 vs base case result the amount of fertilizer produced in the US increases by 67%, 639% and 36% respectively for anhydrous, urea and liquid, with the largest increase in urea.

[5] Volume of shipments are reported in U.S. tons (2000 pounds).

Table 1. US Capacity, Production, Demand and Excess Capacity, Base Case, Future Case and Change, by Type.

	Anhydrous Tons	Dry Tons	Liquid Tons
Base Case: 2012			
US Capacity	14,573,000	7,427,000	12,910,000
US Production	2,610,045	742,700	8,771,962
Total Demand	4,277,360	5,964,799	11,729,348
Excess US Capacity	11,962,955	6,684,300	4,138,038
Future Case			
US Capacity	21,717,000	14,241,000	20,326,000
US Production	4,369,335	5,490,935	11,887,897
Total Demand	4,518,417	6,295,410	12,179,994
Excess US Capacity	17,347,665	8,750,065	8,438,103
Change			
US Capacity	7,144,000	6,814,000	7,416,000
US Production	1,759,290	4,748,235	3,115,934
Total Demand	241,057	330,611	450,646
Excess US Capacity	5,384,710	2,065,765	4,300,066

As suggested, not all proposed projects will be implemented, nor will the entrants necessarily operate at capacity. The model was used to determine the plants that would be most valuable for future expansion from existing capacity. Shadow prices for the plants that would be operating at capacity are shown in Table 2. For urea, the plants that would have the greatest shadow price are located in Louisiana. These values are in the area of $20/t. All other plants are operating at less than capacity and thus the shadow prices are nil. For liquid, those plants with the greatest shadow price include plants in WY, IA, LA and the southern Midwest. These range from as high as $57 and decline to less than $10/t.

Table 2. Shadow Prices for Capacity Constrained Plants, Future Case for Dry and Liquid Plants.

	Location	Shadow Price $/ton
Dry Plants		
PCS Nitrogen Fertilizer L.P.	Louisiana	-21.48
CF Industries Inc.	Louisiana	-20.92
Liquid Plants		
Dyno Noble Inc.	Wyoming	-57.39
CF Industries Inc.	Iowa	-42.58
PCS Nitrogen Fertilizer L.P.	Georgia	-43.09
PCS Nitrogen Fertilizer L.P.	Louisiana	-38.46
CF Industries Inc	Louisiana	-38.46
Koch Nitrogen Company	Nebraska	-32.72
Koch Nitrogen Company	Oklahoma	-15.55
Koch Nitrogen Company	Kansas	-15.18
CHS Inc.	North Dakota	-9.14
PCS Nitrogen Fertilizer L.P.	Ohio	-6.29
OCI North America	Iowa	-2.90

The model determined plant production by type of fertilizer and are shown in Table 3 for each of the proposed new plants. These results show the competitive utilization rates by type of fertilizer. It is clear that many of the proposed plants will operate at much less than capacity and/or would do so for at least the capacity for one of the fertilizer types. As illustrated, only a few plants would be fully utilized. These include plants in Louisiana for anhydrous, urea plants in Louisiana and Iowa; and liquid capacity at Louisiana, and numerous other states. Also, there are a number of plants that would operate at extremely low utilization rates.

The model also determined fertilizer flows, by type, from origin of imports of domestic processing, by route, to consumption points which are counties. Ultimately these are captured in maps but the complexity and volume are too great to show here. For illustration we show the anhydrous flows for the 2018 projection period in Figure 4.[6] At the aggregate level, the effect of these changes can be summarized. For anhydrous, each of the upper Midwest new plants are competitive and operate at least partially (none of them are at capacity). The major changes in flows include increased shipments from plants located in Louisiana, increases in barge shipments, reduced imports from both Canada and through the US Gulf. There are changes in flows related to the new plants in eastern North Dakota, Idaho and Northern Texas.

[6] Similar figures are available from the authors for each type of fertilizer, and scenario.

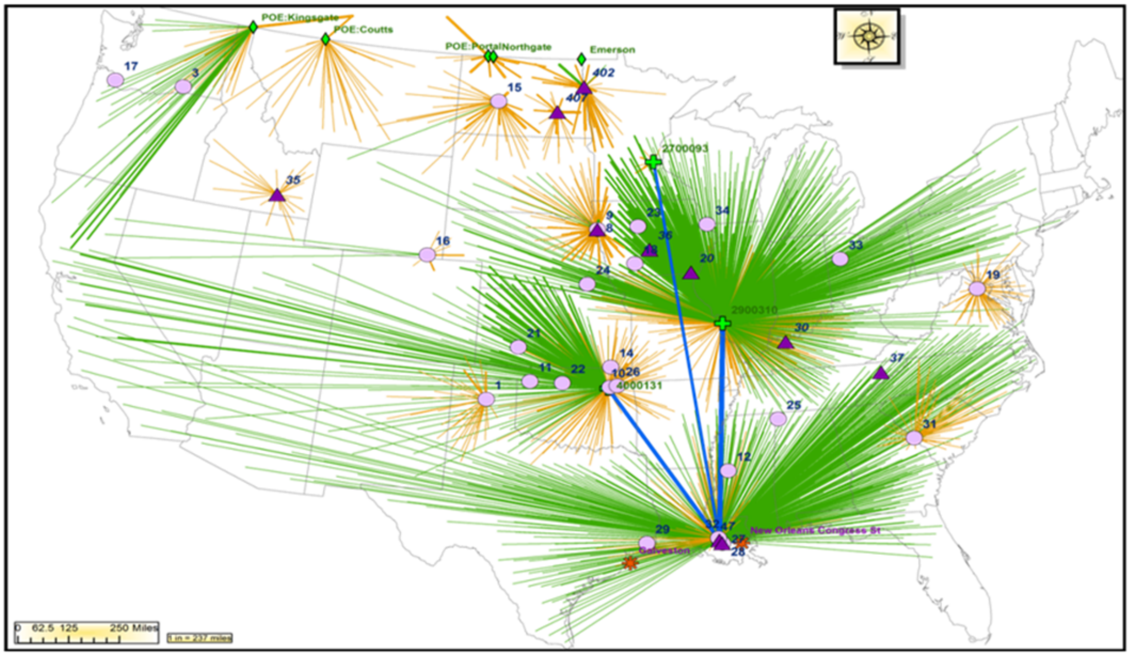

Figure 4. Future Case 2018 Flows For Anhydrous Ammonia.

There would also be fairly drastic changes in urea shipments. Each of the upper Midwest new plants are competitive and operate at least partially (none of them are at capacity). This production largely displaces rail from Galveston to these regions. Major changes in flows include: Reduction in Texas Galveston rail shipments and barge-ex-St Louis rail flows; increased shipments from the Louisiana plants, and Canadian imports.

There would also be changes in the flows of liquid fertilizer. Each of the upper Midwest new plants are competitive and operate at least partially (none of them are at capacity). Major changes in flows include reductions in imports, reduced flows from St. Louis, and increased shipments from the Louisiana plants. Most of liquid shipments out of LA plants goes via barge with slight truck and minimal or no rail.

The model was also used to derive market boundaries for each plant, and by type of fertilizer. Developing market boundaries is complicated due to the multitude of plants, modes, products, and disparate regions in which some plants compete. Analytically, the market boundaries were determined within the solution algorithm. Separate market boundaries were derived for each fertilizer type and plant. The output reported here is the market boundary for the total production and combined truck and rail (i.e. total market).

Table 3. Capacity and Utilization of New Plants, 2018 Case.

Origin	Firm Name	Orig State	Capacity (000 Tons)	Shadow Price ($/Ton)	Type	Utilization
1	Agrium U.S. Inc.	Texas	540	0	Anhydrous	8.2%
4	CF Industries Inc.	Louisiana	2985	0	Anhydrous	59.3%
7	Eurochem	Louisiana	1274	0	Anhydrous	100.0%
8	CF Industries Inc.	Iowa	380	0	Anhydrous	8.5%
9	CF Industries Inc.	Iowa	849	0	Anhydrous	34.5%
15	Dakota Gasification Co.	North Dakota	1181	0	Anhydrous	7.7%
16	Dyno Noble Inc.	Wyoming	196	0	Anhydrous	10.0%
19	Honeywell International Inc	Virginia	620	0	Anhydrous	0.8%
31	PCS Nitrogen Fertilizer L.P.	Georgia	867	0	Anhydrous	0.2%
32	PCS Nitrogen Fertilizer L.P.	Louisiana	500	0	Anhydrous	100.0%
35	Southeast Idaho Energy	Idaho	182	0	Anhydrous	6.9%
100	Agrium U.S. Inc.	Texas	659	0	Dry	27.7%
102	CF Industries Inc.	Louisiana	1680	-21	Dry	100.0%
103	CF Industries Inc.	Louisiana	686	-21	Dry	100.0%
104	CF Industries Inc.	Iowa	50	0	Dry	100.0%
105	CF Industries Inc.	Iowa	1348	0	Dry	83.0%
109	Dyno Noble Inc.	Wyoming	105	0	Dry	23.7%
112	Koch Nitrogen Company	Oklahoma	2055	0	Dry	6.7%
113	Koch Nitrogen Company	Iowa	190	0	Dry	9.8%
117	PCS Nitrogen Fertilizer L.P.	Georgia	623	0	Dry	2.8%
118	PCS Nitrogen Fertilizer L.P.	Louisiana	446	-21	Dry	100.0%
121	Southeast Idaho Energy	Idaho	655	0	Dry	14.3%
122	Texas Clean Energy Project	Texas	700	0	Dry	4.9%
197	Agrium U.S. Inc.	California	225	0	Liquid	19.4%
198	CF Industries Inc.	Louisiana	2415	-38	Liquid	100.0%
199	Eurochem	Louisiana	1768	-38	Liquid	100.0%
200	CF Industries Inc.	Iowa	800	-43	Liquid	100.0%
201	CF Industries Inc.	Oklahoma	1965	0	Liquid	13.6%
202	CF Industries Inc.	Oklahoma	800	0	Liquid	34.3%
204	Coffeyville Resoures LLC	Kansas	1050	0	Liquid	4.0%
205	Dyno Noble Inc.	Wyoming	210	-57	Liquid	100.0%
206	Dyno Noble Inc.	Oregon	62	0	Liquid	5.1%
207	Iowa Fertilizer Co.	Iowa	1462	0	Liquid	58.5%
208	J.R. Simplot Company	California	230	0	Liquid	13.7%
209	Koch Nitrogen Company	Nebraska	200	-33	Liquid	100.0%
210	Koch Nitrogen Company	Kansas	255	-15	Liquid	100.0%
211	Koch Nitrogen Company	Oklahoma	90	-16	Liquid	100.0%
212	Koch Nitrogen Company	Iowa	540	0	Liquid	92.5%
213	LSB Industries Inc.	Alabama	289	0	Liquid	28.8%
216	PCS Nitrogen Fertilizer L.P.	Georgia	640	-43	Liquid	100.0%
217	PCS Nitrogen Fertilizer L.P.	Louisiana	1133	-38	Liquid	100.0%
218	PCS Nitrogen Fertilizer L.P.	Ohio	250	-6	Liquid	100.0%
220	Southeast Idaho Energy	Idaho	528	0	Liquid	19.3%
401	Summit Energy/CHS	Texas	700	0	Dry	3.4%
402	Northern Plains Nitrogen	North Dakota	2200	0	Anhydrous	9.1%
403	OCI North America	Iowa	1400	-3	Liquid	100.0%
404	CHS Inc.	North Dakota	790	0	Dry	71.5%
405	CHS Inc.	North Dakota	238	-9	Liquid	100.0%
407	CHS Inc.	North Dakota	210	0	Anhydrous	59.7%
408	Northern Plains Nitrogen	North Dakota	800	0	Dry	51.6%
409	Northern Plains Nitrogen	North Dakota	500	0	Liquid	57.4%

The market boundaries are shown in Figures 5a, 5b and 5c for each of the fertilizer types. These are shown only for the upper Midwest due to the complexity and interest for this study, though market boundaries were created for each plant in the United States. The results indicate that for anhydrous each of the ND plants operate and, compete with imports from Canada (green). Beulah ships to central ND and south and west as far as WY. Each of Spiritwood, Grand Forks and Beulah in North Dakota compete but are bounded in the north by imports and in the south by shipments from the Iowa plant. Very intense competition that will emerge in South Dakota between the ND and Iowa plants. The Iowa plant has higher NG prices, but, lower costs due to size.

The changes for urea are similar. Imports from Canada are important and each of Grand Forks and Spiritwood operate. Beulah does not operate due to high costs (small plant and high costs). There will be intense competition from Iowa (lower cost and larger). These market boundaries indicate major competitive battles over South Dakota. The North Dakota plants have lower natural gas prices, but limited by capacity; Iowa plant has higher natural gas, but larger plant capacity. The results for liquid differ slightly because Beulah does not produce UAN. Imports for this product are substantive. Both Spiritwood and Grand Forks are large producers and penetrate to southerly counties. Finally, there are substantial changes in flows for each mode. The model derived the changes in flows for each mode. Anhydrous rail volume increases by 645,000 t, urea decreases by 2122 t and liquid decreases by 92,000 t. The change in urea shipments is substantial and is comprised partly by the large reduction in shipments from Galveston which are displaced partly by local processing in the upper Midwest.

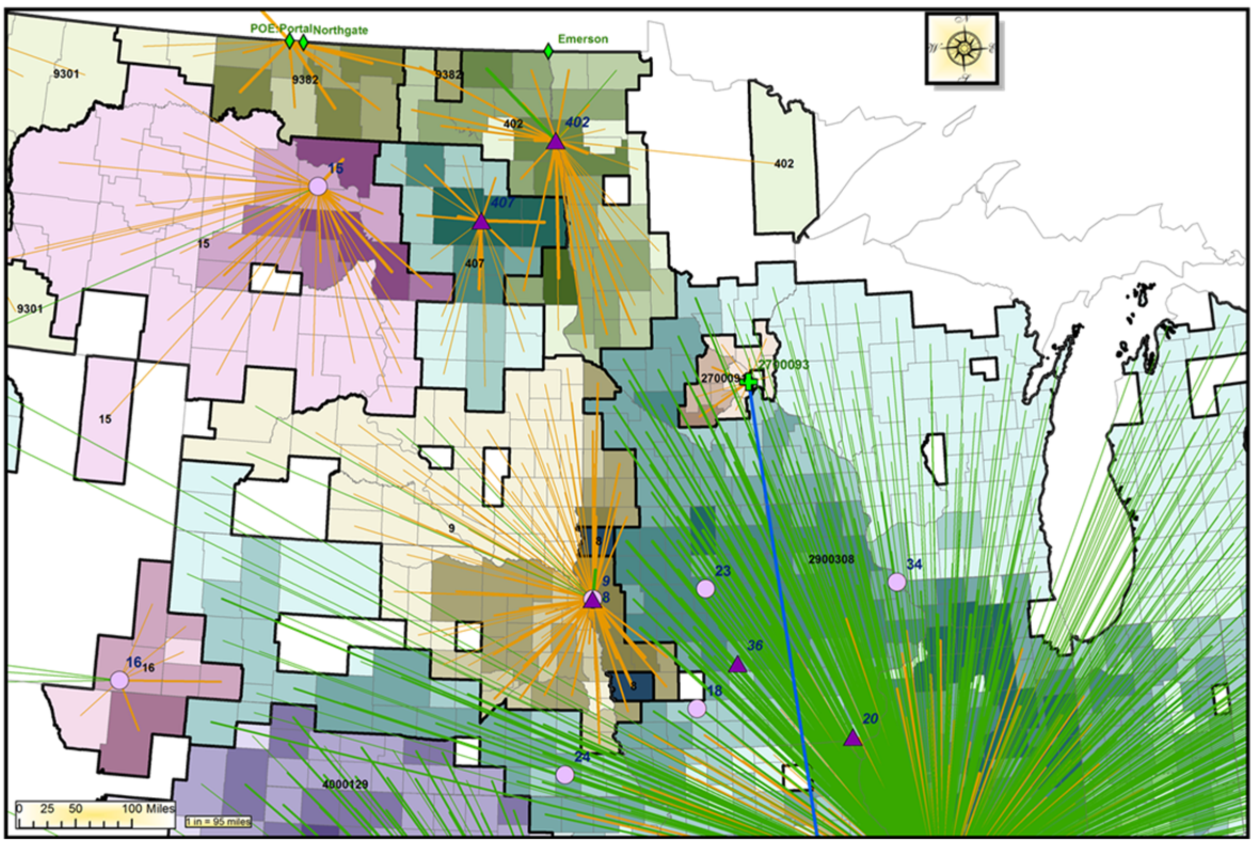

Figure 5a Market Boundaries for Upper Midwest Future Case, 2018 Anhydrous Ammonia.

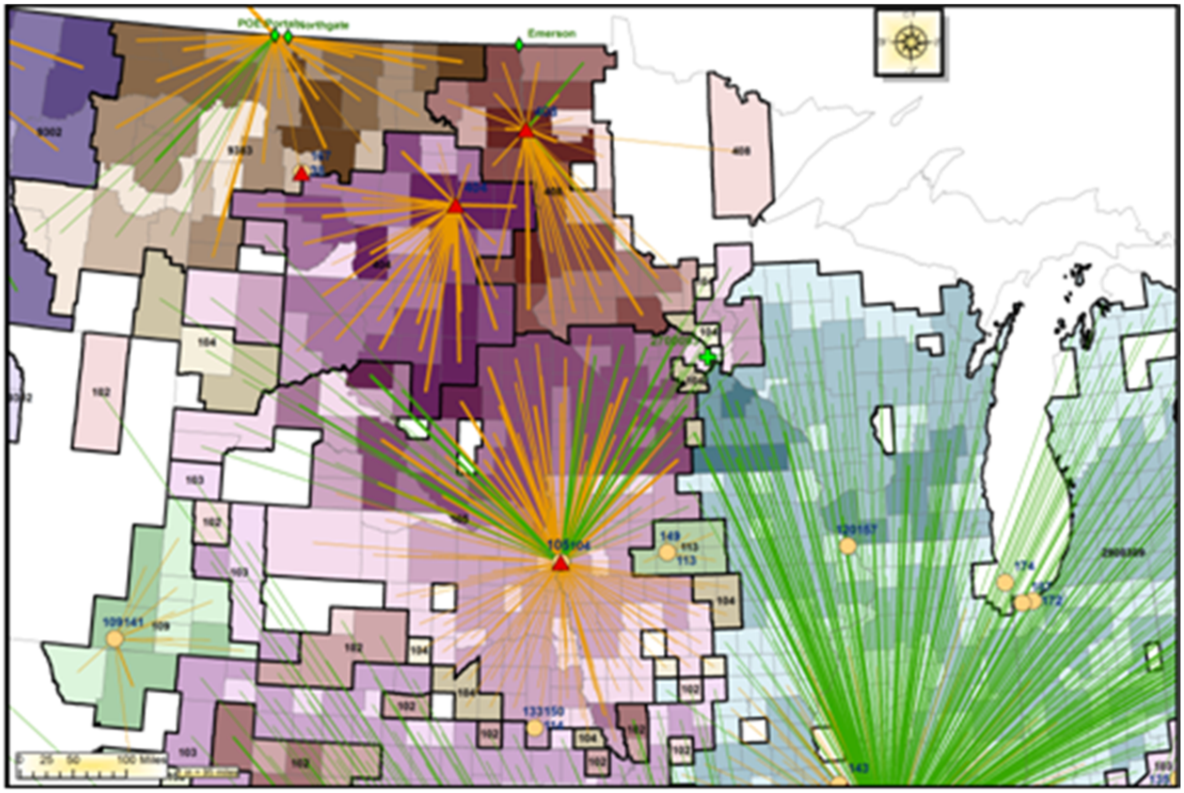

Figure 5b. Market Boundaries for Upper Midwest Future Case, 2018 Dry.

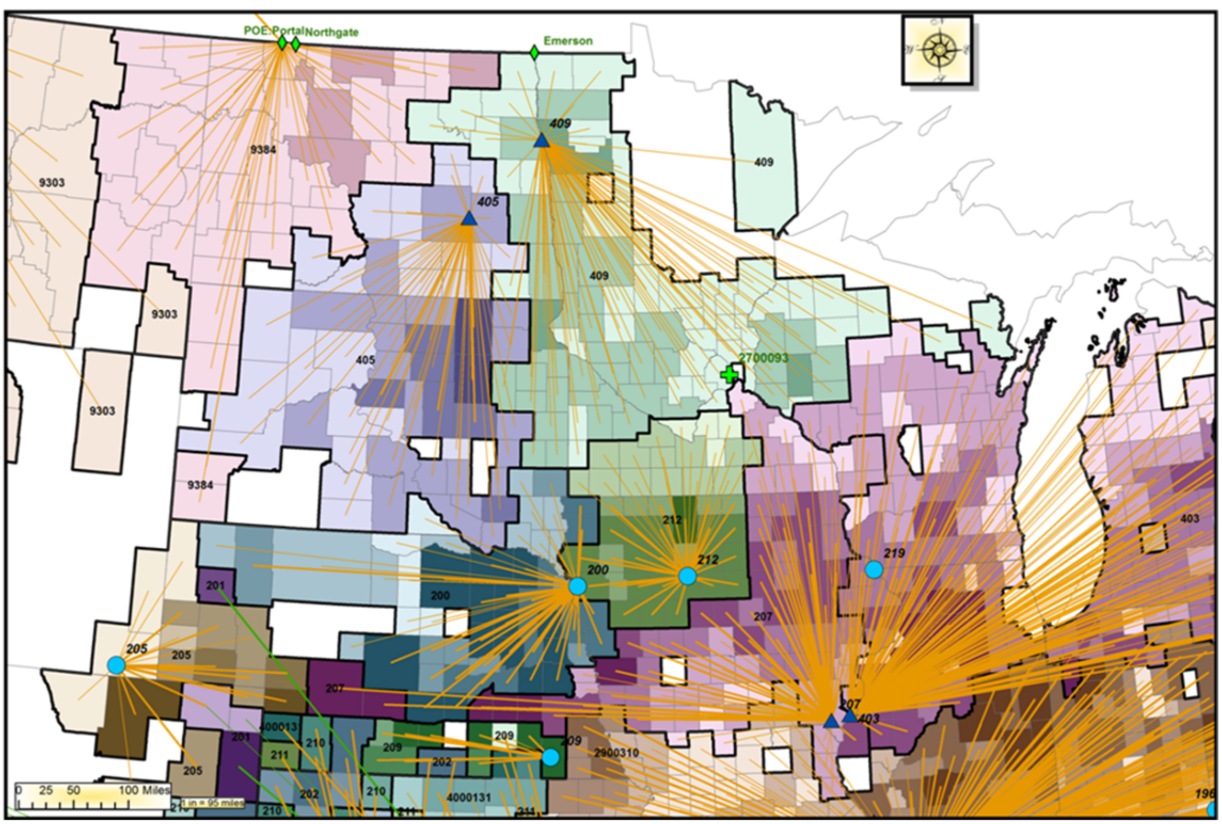

Figure 5c. Market Boundaries for Upper Midwest Future Case, 2018, Liquid.

Sensitivities The model was used to conduct a number of sensitivities and the results are presented below.

<u>Composition of Competitors:</u> The results above are a bit naïve in that it assumes that each proposed new project is developed. The model determines the production level of each plant but as shown above there are a large number of plants that are severely underutilized. Several restrictions were imposed on the model to capture impacts of differing levels of entry and production of new plants. The results are all shown in Table 4 with comparisons to the 2018 case as depicted above.

Table 4. Sensitivities: Impacts of Exogenous Changes on Spiritwood/Grand Forks Plants.

Location	Firm	Type	Capacity (000 Tons)	Base Case (000 Tons)	Future 1 (000 Tons)	Spiritwood Only (000 Tons)	Spiritwood, Grand Forks, Beulah (000 Tons)	Beulah only (000 Tons)
Spiritwood	CHS, Inc	Anhydrous	210	0	125	210	210	0
Spiritwood	CHS, Inc	Dry	790	0	564	790	601	0
Spiritwood	CHS, Inc	Liquid	238	0	238	238	238	0
Grand Forks	NPN	Anhydrous	2200	0	201	0	0	0
Grand Forks	NPN	Dry	800	0	413	0	600	0
Grand Forks	NPN	Liquid	500	0	287	0	464	0
Beulah	Dakota Gasification	Anhydrous	1181	387	91	101	101	272
Beulah	Dakota Gasification	Dry	385	0	0	0	0	0
Port Neal	CF Industries	Anhydrous	380	353	325	380	380	380
Port Neal	CF Industries	Dry	50	5	1169	1398	1398	1398
Port Neal	CF Industries	Liquid	800	800	800	800	800	800
				Utilization	Utilization	Utilization	Utilization	Utilization
Spiritwood	CHS, Inc	Anhydrous		0	60%	100%	100.0%	0%
Spiritwood	CHS, Inc	Dry		0	71%	100%	76.1%	0%
Spiritwood	CHS, Inc	Liquid		0	100%	100%	100.0%	0%
Grand Forks	NPN	Anhydrous		0	9%	0%	0.0%	0%
Grand Forks	NPN	Dry		0	52%	0%	75.0%	0%
Grand Forks	NPN	Liquid		0	57%	0%	92.8%	0%
Beulah	Dakota Gasification	Anhydrous		33%	8%	9%	8.6%	23.1%
Beulah	Dakota Gasification	Dry		0	0%	0%	0.0%	0.0%
Port Neal	CF Industries	Anhydrous		93%	26%	100%	100%	100%
Port Neal	CF Industries	Dry		10%	84%	100%	100%	100%
Port Neal	CF Industries	Liquid		100%	100%	100%	100%	100%

Future 1 includes all future plants deemed as likely to be built as options.
Spiritwood only only allows Spiritwood ND as option of the 3 North Dakota New Plants
Spiritwood, Grand Forks and Buelah allows all 3 North Dakota New Plants
Buelah only allows the Buelah plant as the only North Dakota New Plant.

One model specified that a plant would only be adopted if it operated at a minimum of 75% of annual capacity. This restriction is not exactly magical but reflects the need of any new plant to be large enough to exploit the economies of scale to justify its investment and cover operating costs. Technically this is solved as a mixed integer linear programming model. The results determine which of the proposed plants could enter and produce at a rate of 75% capacity.

The results indicate that the plants that would be compatible with this restriction are: Eurochem, in LA, Spiritwood, ND, Grand Forks, for anhydrous, urea and liquid respectively and dry and liquid plants in Wever, IA, dry plants in Port Neal, IA, Enid, OK, Borger, TX, and Beulah, ND.

As a result of these new plants, there are some major changes in flows. For anhydrous there is an increase in shipments from the Louisiana plants and imports from both Canada and US Gulf are reduced. The changes in urea shipments are for a substantial reduction in Texas Galveston rail shipments, an increase in shipments from Louisiana plants, and Canadian imports increase for Northern North Dakota and Eastern Montana. Finally, for liquid fertilizer, the plants in Spiritwood and Iowa are developed. Changes in flows are for reduced Canada imports and an increase in shipments from Louisiana.

The model was also used to evaluate the impacts of the proposed Eurochem plant in Louisiana. This plant is important in part because it would be low cost relative to others. Further, they recently acquired land for the project (Area Development Online, 2013) which may suggest it will have a greater chance of moving forward. The model simulated impacts of this plant on spatial competition. Results indicated that the Eurochem plant would operate at capacity for production of dry and liquid nitrogen, while the anhydrous ammonia plant would operate at about 45% capacity.

International Prices: The model was also used to explore the prospective impacts of international fertilizer prices on US spatial competition. The base case used values for Urea at $290/t and others as noted above, which were the average during the base period. The model was re-run assuming much lower international prices at 339/t, 200/t and $214/t for anhydrous, urea and liquid respectively. These values are important because ultimately fertilizer produced domestically would have to compete with imported fertilizer.

The results indicate that at these lower levels of import prices, there would be a shift toward more imports through the US Gulf. The most significant change in flows is in urea. In this case the level of imports through the US Gulf would increase by about 1 million tons, and imports from Canada would decrease. The impact of this type of change would also reduce the domestic production, primarily in the upper Midwest, by about 850,000 tons.

Summary and Implications

The fertilizer in the United States is going through some important changes. Most important, are 1) the increase in demand for fertilizer due in part to higher yields and changes in the composition of crops being produced; 2) the tremendous expansion for processing within the US; and 3) changes in natural gas prices resulting in lower values, and in much more spatially heterogeneous prices. The impact is important since about 50% of the cost of fertilizer manufacturing is comprised of natural gas prices.

The purpose of this study was to analyze spatial competition in the United States nitrogen fertilizer sector and to determine the likely future spatial distribution of production and flows for nitrogen fertilizer. A spatial competitive model was specified and solved using optimization techniques and jointly with spatially defined GIS inputs and outputs. A base case was specified and compared to the impacts of projected for important variables to the year 2018. The results indicate the likely change in distribution of production, as well as flows from production areas to county level demands.

The most valuable (lowest cost) origins for US processing are primarily in Louisiana, followed by others states with low natural gas prices. Shadow prices indicate several locations in Wyoming, Iowa, Georgia, Louisiana, Nebraska, Kansas, and North Dakota would be positive. While there are about 25 proposed fertilizer projects, these results indicate that not all of these would be viable. This is particularly true if all were built in which case many would operate at substantially less capacity. In a model specification that required any new plant to have a capacity utilization rate of 75% or more, the results change. In this case there would be only a few new plants including those located in Louisiana, Iowa and North Dakota.

Given these changes, there would be substantial changes in the flows and distribution of these products. Generally it will result in reduced long-haul rail shipments and prospectively replaced by shorter-haul shipments competing with trucks. Rail volume would decrease substantially in some routes. The results indicate rail shipments would decline prospectively by 1.6 million tons (-23%) compared to the base case solution. Results indicate that more likely, imports and shipments from import ports will decline and be replaced mostly by domestically produced products. Of particular importance is the prospective reduction in rail shipments from Galveston.

There are several contributions from this study. One is an exploration of the impacts of changes of one of the important input industries in US agriculture. There have been a number of broader descriptive studies in fertilizer, and several that have suggested the nature of forthcoming changes, but, none have quantified these impacts. Second, a very detailed model of supply chain costs was specified. Third, is that detailed demand and costs were used as inputs into the model. All of these provide detail necessary to understand future competitive environment in this industry.

The implications of these results are important for the entire industry. For growers, all these results should be viewed as positive. The combination of new entrants producing at lower cost ultimately will result in lower cost fertilizer, and more likely less volatile prices due in part that they will be produced with domestic natural gas which are declining in value. The implications for the fertilizer industry are probably more dramatic. This is an industry characterized by volatile demands, and large scale manufacturing which are high fixed and low marginal costs. Further, the nature of the entrants/expanders is such that they have differing motives for entry. In the end, incumbents will face more entrants which are more heterogeneous in several respects. These reasons all suggest that there will probably be more new plants than are needed, they will be operating in a market with volatile demands and declining marginal costs.

As a result, there will likely be ruinous competition. The impact of this would result in suppliers seeking to differentiate their products and distribution systems to seek competitive advantages.

There are also implications for the rail industry. One is for a net reduction in demand for shipments. Longer-haul movements from the US Gulf will be replaced by locally produced fertilizer. Instead, the industry will be demanding short-haul shipments. For the railroad, that means they may have to develop efficient shorter-haul shuttles to compete and contribute to shipments in this sector. There will be intense inter-market competition to serve South Dakota. Plants in North Dakota and Iowa would each serve this market and it is a large market with/no incumbents; but, each of the ND and Iowa plants could penetrate by truck or rail.

References

AAPFCO. 2011. Commercial Fertilizers 2011 Association of American Plant Food Control Officials and The Fertilizer Institute. Washington D.C.

Area Development Online. 2013. Russian-based EuroChem Seeks to Build $1.5 Billion Fertilizer Manufacturing Plant in Louisiana. 7/10/2013. http://www.areadevelopment.com/newsItems/7-10-2013/eurochem-production-plant-louisiana348923.shtml

BNSF. 2013a. BNSF Item 90084 Anhydrous Ammonia. http://www.bnsf.com. Accessed 5/31/2013.

BNSF. 2013b. BNSF Item 90004 RR_Price_Authority_Details Urea. http://www.bnsf.com. Accessed 5/31/2013.

BNSF. 2013c. BNSF Item 90004-Tank_Price_Authority, Liquid. http://www.bnsf.com. Accessed 5/31/2013.

Casavant, Ken , Marina Denicoff, Eric Jessup, April Taylor, Daniel Nibarger, David Sears, Hayk Khachatryan, Vicki McCracken, Eric Jessup, Marvin Prater, Jeanne O'Leary, Nick Marathon, Brian McGregor, and Surajudeen Olowolayemo. 2010. Study of Rural Transportation Issues, U.S. Department of Agriculture, Agricultural Marketing Service, April. Web. http://dx.doi.org/10.9752/TS041.04-2010

Debertin, J. 2012. Prairie Grains Conference. December 12-13, 2012

eAmmonia, 2013. Is Ammonia Boom in North America Peril for Trinidad Ammonia Plants.

Economist. 2011a. The 9 billion-people question, Feb 24 2011.

Economist. 2011b. Feeding the world, special edition, Feb 26 2011.

EIA. 2013a. Natural Gas Industrial Price by State. http://www.eia.gov/dnav/ng/ng_pri_sum_a_epg0_pin_dmcf_m.htm Accessed 6/3/2013.

EIA. 2013b. Average Retail Price of Industrial Electricity by State. http://www.eia.gov/electricity/data/browser/#/topic/7?agg=1,0&geo=g0fvvvvvvvvo&endsec=2&freq=A&start=2001&end=2012&ctype=columnchart&ltype=pin&pin=&rse=0&maptype=0 Accessed 6/7/2013.

Green Markets. 2014. Fertilizer Market Data, News and Analysis. Available at http://www.fertilizerpricing.com/.

IFDC. 2013. North American Fertilizer Capacity. Market Information Unit of Office Programs, IFDC, Muscle Shoals, AL. March.

Huang, W. 2007. Impact of Rising Natural Gas Prices on U.S. Ammonia Supply, USDA ERS Report WR0702. 2007.

Kelleher, D. 2013. "CF Industries Holdings, Inc." presentation to Citigroup 6th Annual Basic Materials Symposium, available at http://phx.corporate-ir.net/phoenix.zhtml?c=190537&p=irol-presentations

Lamp, G. 2013. Home Field Advantage, CHS Inc. pp. 7-10; January-February 2013.

Leonard, C. 2014. The New Koch, Fortune Magazine, pp. 60-67.

Maung, Thein, David Ripplinger, Greg McKee and David Saxowsky. 2012. Economics of Using Flared vs. Conventional Natural Gas to Produce Nitrogen Fertilizer: A Feasibility Analysis. Department of Agribusiness & Applied Economics, North Dakota State University, Fargo. AAER 699.

Olson, Kent, Michael Rahm, and Michael Swanson. 2010. Market Forces and Changes in the Plant Input Supply Industry. Vol. 25(4)

Prud'homme, Michel. 2005. Global Nitrogen Fertilizer Supply and Demand Outlook. Science in China. Vol. 48(818): 818-826.

River Transport News. 2013. Spot Northbound Dry Cargo Barge Rates ($/ton).

Rosas, Francisco. 2011. World Fertilizer Model-The World NPK Model. Center for Agricultural and Rural Development Iowa State University, April. Working Paper 11-WP 520.

Statistics Canada. 2013. Fertilizer Shipments Survey. Catalogue no. 21-022-X. Available from www.statcan.gc.ca.

USDA-NASS. 2013a. Planted acres by crop by county. http://quickstats.nass.usda.gov/. Accessed May, 16, 2013.

USDA-NASS. 2013b. Agricultural Chemical Use Program Survey Data on Fertilizer use by crop. http://www.nass.usda.gov/Surveys/Guide_to_NASS_Surveys/Chemical_Use/index.asp Accessed May 17, 2013

USDA-ERS. 2013a. Fertilizer use and Price. http://www.ers.usda.gov/data-products/fertilizer-use-and-price.aspx#.UsxvDVAXZmp Accessed May 17, 2013.

USDA-ERS. 2013b. Fertilizer Import/Export Data. http://www.ers.usda.gov/data-products/fertilizer-importsexports.aspx#.Us1owlAXZmo Accessed May 10, 2013

Williamson, T. 2012. Oil Shale Production: Impacts on US Energy.

Wiser, Mike. 2013. Why fertilizer plants target Iowa, Quad Cities Times, March 30 2014. Available at http://qctimes.com/news/local/why-fertilizer-plants-target-iowa-midwest/article_f01b9eee-99b1-11e2-99db-0019bb2963f4.html

World Bank, 2013. Commodity Markets Outlook, Vol. 2 July 2013.

Zilberman, D., B. Dale, P. Fixen, and J. Havlin. 2013. Food, Fuel, and Plant Nutrient Use in the Future, CAST Issue Paper No. 51. March 2013

Yara. 2010. Yara Industry Fertilizer Handbook 2010. Available at http://www.yara.com/doc/32948_2010_Fertilizer_Industry_Handbook_web.pdf

Yara. 2012. Yara Industry Fertilizer Handbook 2012. Available at http://www.yara.com/doc/37694_2012%20Fertilizer%20Industry%20Handbook%20wFP.pdf