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Dynamic changes in spatial competition for the nitrogen fertilizer industry in the United States

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ABSTRACT

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 US nitrogen fertilizer industry was developed to determine the likely future spatial distribution of production and flows for nitrogen. The model minimizes production and shipping costs from plants and imports to consuming regions. A base model of 2010–2012 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 other states with low natural gas prices. Shadow prices indicate 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.

1. Introduction

Major changes are evolving in the US 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 in this industry. 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 ranging from about $1.5 to 3.0 billion. The combination of these is resulting in substantial pressures on the North American fertilizer industry which will have far reaching impacts on US agriculture.

The purpose of this study is to analyze spatial competition in the US fertilizer sector and to determine likely future spatial distribution of production and flows for nitrogen. 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. 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.

2. Background and dynamic changes

2.1. 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, 2011b). The United States is one of the major users of nitrogen fertilizer, though growth in use in other countries is accelerating. Fertilizer demand varies across crops and regionally.

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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 implications for spatial competition. Nitrogen fertilizer use by type also varies substantially across states (AAPFCO, 2011). There are three primary types of nitrogen fertilizer; anhydrous ammonia, urea and UAN (liquid).[1] There are substantial differences in demand for these types across states. 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 scattered throughout the Midwest. In addition, the industry imported significant amounts of fertilizer. These shipments 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.

Import and domestic prices are extremely volatile, and impact domestic plant utilization. Urea prices at the US Gulf have ranged from $100 to 200/t in the early 2000s to a peak of over $800 in 2008 and nearly that level again in 2012, and have 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/t. 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.

Finally, the breadth and scope of new entrants is important. Since about 2011 there have been many announcements for new plants. In total, about 25 new plants have been proposed, each proposed to produce in the area of 1.1 to 3.7 million tons/year and costing in the area of $1.5 to $3.0 billion. 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.

2.2. Previous studies

A number of recent studies provide perspective on these emerging changes.[4] Prud'homme (2005) discussed trends and outlook for nitrogen fertilizer production, use and trade. He 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.

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). Yara (2010, 2012) provides a detailed description of the underlying demand, pricing and costs for nitrogen fertilizer. Hildebrant (2013) and Lamp (2013) explained the logic of the proposed plant to be built by CHS. A recent presentation by CF Industries (Kelleher, 2013) indicated returns to their new plants ranged from 14 to 20% depending on natural gas and urea prices.

There have been 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 geography of production. Casavant et al. (2010) indicate the issues facing the US fertilizer industry include price volatility, transportation policies and long-term increases in fertilizer use. Zilberman et al. (2013) analyzed the future demand for food and pointed 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 a model of world fertilizer demand, tied into the world FAPRI projections model. Olson et al. (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.

3. Model specification

3.1. Overview

The analytical framework is a spatial network flow model of the US fertilizer industry and used to analyze production, imports, and flows from origins to destinations. Activities include producing nitrogen fertilizer in existing and proposed plants, importing fertilizer and shipping. Costs are derived for each activity. Fertilizer plants are at actual locations and locations for proposed new plants. Imports are through the US Gulf (Louisiana and Texas) and from Canada. Each activity is modeled for the 3 types of nitrogen fertilizer, anhydrous ammonia, dry (urea) and liquid (UAN).

Demand is determined at counties for each crop and fertilizer type. 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 inland destinations.

The model is calibrated and solved for the base case period which is 2010–2012. Projections are made for the important exogenous

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

[2] Green Markets (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.

[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 not reviewed here.