A Time Series Approach to Retrospective Merger Analysis: Evidence in the US Nitrogen Fertilizer Industry

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Abstract

Nitrogenous fertilizer prices spiked in early 2010 despite the fact that natural gas prices, nitrogen fertilizer's main production cost, have dramatically fallen during this time period. We hypothesize that a merger which occurred between CF and Terra industries in 2010 exacerbated market power in an already concentrated industry, causing nitrogen fertilizer prices to increase.

To test this hypothesis, we propose a structural vector autoregressive (SVAR) model. By including corn futures, natural gas and nitrogen fertilizer prices within an SVAR model we control for demand and supply shocks which affect the nitrogen fertilizer market. The remaining variation in fertilizer prices at 2010 not explained by the model is attributed to the merger. If we set this residual to zero, we can then use the SVAR model to forecast a counterfactual fertilizer price series which represents the price of nitrogen fertilizer in the absencebsence of the merger. Applying this technique to the data suggests that the merger raised prices by roughly 75%.

This approach presents a middle-ground between the current methodologies used in the retrospective merger analysis literature. It is more transparent than structural approaches such as Nevo (2000) which make strong assumptions on demand and market conduct. Conversely, this time series approach is more applicable than the reduced form approaches such as Hastings (2004) that employ a difference in difference method and consequently rely on the existence of a credible control group.

A Time Series Approach to Retrospective Merger Analysis: Evidence in the US Nitrogen Fertilizer Industry

Over the course of the last decade prices of nitrogenous fertilizers have drastically increased. The price paid for ammonia by US farmers, the principle component in nitrogen fertilizer, has moved from $227 a ton in 2000 to $780 a ton in 2012, a 200% increase. While there is some controversy over what has caused these drastic price changes, Huang (2007) suggests that volatile and growing natural gas prices during this time period are the main contributing factor. Natural gas is by far the most important input in the production of nitrogen fertilizer accounting for 90% of total production costs, TFI (2005).

Curiously, the advent of hydraulic fracturing and horizontal drilling that has caused domestic natural gas prices to plummet has not reduced nitrogen fertilizer prices. Despite facing the lowest natural gas prices in 10 years, the price of nitrogen fertilizer has continued to grow, leading to the largest natural gas to ammonia price spread in the history of the industry.

As natural gas prices began to decrease in 2009, several large fertilizer corporations attempted to acquire other fertilizer corporations. CF industries was the only firm which was successful, acquiring Terra industries on March 2010. At the time of the merger, CF industries and Terra industries where the 2^{nd} and 1^{st} largest US firms by production capacity. After the merger, CF industries had more capacity than the next three largest US firms combined. It is possible that this large merger exacerbated

market power in a concentrated industry that had previously been characterized as imperfectly competitive by Gopinath and Wu (1999). This increase in market power may in turn explain the decoupling of ammonia and natural gas prices as the industry strays further from marginal cost pricing. The remainder of this paper will test this hypothesis by measuring how fertilizer prices were affected by the 2010 merger.

A structural vector autoregressive (SVAR) model is used to estimate the effects of the 2010 merger. The intuition behind this model is simple. Nitrogen fertilizer prices are determined by supply and demand shocks. Such shocks can be controlled for by including natural gas and corn prices along with fertilizer prices in the SVAR model. Intuitively, after controlling for natural gas and corn prices, the large fertilizer price shock which occurs in the months after March 2010 can be attributed to the merger. By setting this shock to zero and forecasting prices forward it is possible to generate a counterfactual time series of fertilizer prices which represents the price of nitrogen fertilizer in the absents of the merger.

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Understanding the effects of the CF and Terra industries merger in the nitrogen fertilizer industry is of fundamental importance. Fertilizer is a major input in the production of food and animal feed crops as well as corn used in the production of biofuels. Consequently, high fertilizer prices bolstered by imperfect competition will have substantial welfare effects for farmers as well as consumers.

The remainder of the paper will continue as follows: Section 1 will supply background information on the fertilizer industry. Section 2 will discuss the 2010 merger between CF industries and Terra Industries, as well as related merger literature. Section 3 will present the empirical model. Section 4 discusses data. Finally, section 5 presents estimation and results.

1 Industry Background

Nitrogen is a vital macronutrient for the development of all plants. While nitrogen is the most abundant element in earth's atmosphere, several crops such as corn and wheat are not able to absorb it directly from the air. In an effort to increase yields, farmers apply nitrogen fertilizers to the soil to supplement the presence of this fundamental nutrient. Of the three main macronutrients essential to crop growth, nitrogen, phosphate and potassium, nitrogen is by far the most applied fertilizer by US farmers. Of the 20.8 million tons of fertilizer applied in the United States in 2010, 60% was nitrogen fertilizer. Consequently, nitrogen fertilizer makes up a substantial portion of US farmers' operating costs. In 2005 the purchase and application of nitrogen

fertilizer represented 18% of the operating cost for corn producers and about 30% of the operating cost of wheat producers.

The production of nitrogen fertilizer is accomplished by using the Haber-Bosch process. This process consists of combining natural gas with hydrogen, contained in the surrounding atmosphere, to obtain anhydrous ammonia. Anhydrous Ammonia (AA) is a nitrogen rich colorless gas that is itself a type of nitrogen fertilizer that can be applied directly to the soil; however, it can also processed into more diluted forms such as urea, ammonia nitrate or nitrogen solutions which are easier to apply. Since all fertilizer firms have the ability to produce the various different types of nitrogen fertilizer, the rest of his paper will exclusively discuss market power in the ammonia industry.

Natural gas is converted into ammonia at fixes rates. The amount of natural gas that is needed to produce one ton of ammonia varies across plants from 30 MMBTU per ton to 38 MMBTU per ton, Agrium (2012). Unfortunately, plant level conversion rates are not publicly available. Therefore, it is not possible to obtain estimates of marginal cost directly from accounting and engineering data as Wolfram (1999) and Borenstein, Bushnell and Wolak (2002) do in the electricity industry.

The remainder of the input costs make up between 10 and 25% of the total production cost. These additional costs include electricity, labor, capital and maintenance and are generally used in fixed proportions with natural gas[1].

[1] The Fertilizer Institute (TFI) conducts a production cost survey every 10 years. Unfortunately, I do not currently have access to this document because it is not public information.

Smaller plants, spurred on by high natural gas prices, have rapidly been leaving this industry. To get a sense of the magnitude of change, in 1976 there were 86 plants with capacity less than 250,000 metric tons a year; in 2010 there were a mere 5 plants with a capacity less than 250,000 metric tons. Over the same time period the number of plants with capacity over 500,000 metric tons has almost quadrupled, moving from 4 to 15. As small plants were replaced by larger plants the industry itself became increasingly concentrated. In 1976 there were over 50 ammonia producers, in 2000 there were 27 ammonia producers and as of 2010, this number has dwindled to a mere 13 firms. As small firms left the industry the top four biggest nitrogen fertilizer producers by capacity, Koch, PCS Nitrogen, Agrium and CF Industries, have increased in importance. In 2000 the capacity of the four biggest firms was 43% of the total US capacity but as of 2010 represents nearly 74% of total US capacity.

The nitrogenous fertilizer industry is also protected from foreign competition as a result of anti-dumping duties that were levied in 2000. These duties were a direct response to the growing price spread between US and foreign natural gas. The advent of liquefied natural gas, as well as newly discovered natural gas reservoirs where forcing natural gas price aboard to all-time lows as domestic natural gas prices were skyrocketing. Further, as of 2000, the only economically feasible way to transport large quantities of natural gas was via pipeline. It was therefore expected that the large price spread between the US and countries abroad would persist and therefore these foreign countries would capture a comparative advantage in the production of nitrogen

fertilizer. In light of these facts, US producers of nitrogen fertilizer that included Agrium, CF Industries, Coastal Chemicals, Mississippi Chemical, PCS Nitrogen and Terra Industries successfully had anti-dumping duties placed on several former Soviet Union countries in 2000. Despite pressure in 2006, the anti-dumping duties where renewed in 2011. These antidumping duties did not completely eliminate imports from these countries, rather these countries where required to sell fertilizer at higher prices in the US. As a result of these duties, a large portion of the US imports of ammonia came from Canada and Trinidad and Tobago, where antidumping duties have not been levied. Not surprisingly, the majority of the capacity in these countries is owned by Agrium, CF Industries and PCS Nitrogen.

Despite the level of concentration in the fertilizer industry discussed above, the literature on market power in the fertilizer industry is scarce. Gopinath and Wu (1999) use industry level data that spans from 1960 to 1991 to estimate a New Empirical Industrial Organization model. The authors estimate that an 18% markup exists in the nitrogen fertilizer industry and therefore the industry is not characterized by perfect competition. It is important to note that the level of concentration in the nitrogen fertilizer industry has dramatically increased in the last 20 years, and therefore Gopinath and Wu's estimates are likely to be lower bounds on the current industry level markup.

2 The Merger

The 2010 merger between CF and Terra Industries allowed CF Industries to increase its total capacity to 4,855,000 metric tons per year. This allowed CF Industries

to have more capacity than the next three largest US firms combined. Given the magnitude of the merger, CF and Terra Industries where required by the Hart-Scott-Rodino Act to file a premerger notification to the Federal Trade Commission (FTC) on April 21, 2009. After a second round of information was requested from the merging firms on June 3, 2009, the FTC closed the investigation on the merger on August 6, 2009. Despite the dramatic increase in production capacity that CF Industries acquired, the FTC ruled that the merger did not violate the Clayton act and therefore was allowed to proceed. Interestingly, Agrium, the largest Canadian nitrogen fertilizer company, attempted to acquire CF Industries in early 2009. The FTC required that before Agrium was to acquire CF Industries it had to sell a range of assets in order to prevent anticompetitive behavior. However, Agrium did not comply with these terms and the merger never occurred.

The merger of CF and Terra Industries occurred on March 2010. Shortly after this merger fertilizer prices spiked, as depicted in figure 1. The fertilizer price is represented by wholesale Anhydrous Ammonia (AA) prices in the Cornbelt[2] region of the United States. The marginal cost of AA production in figure 1 is calculated by multiplying the henry hub spot prices by the conversion rate of 34MMBtu/1 Short Ton of AA. Clearly, this estimate of marginal cost is not complete. It ignores other production costs as well as changes to the industry level conversion rate. Despite these

[2] The Cornbelt includes the following states: Iowa, Illinois, Indiana, Missouri, Nebraska and Ohio

limitations, it is clear that fertilizer prices decouple from natural gas prices at the time of the merger, which is signified by the vertical black line.

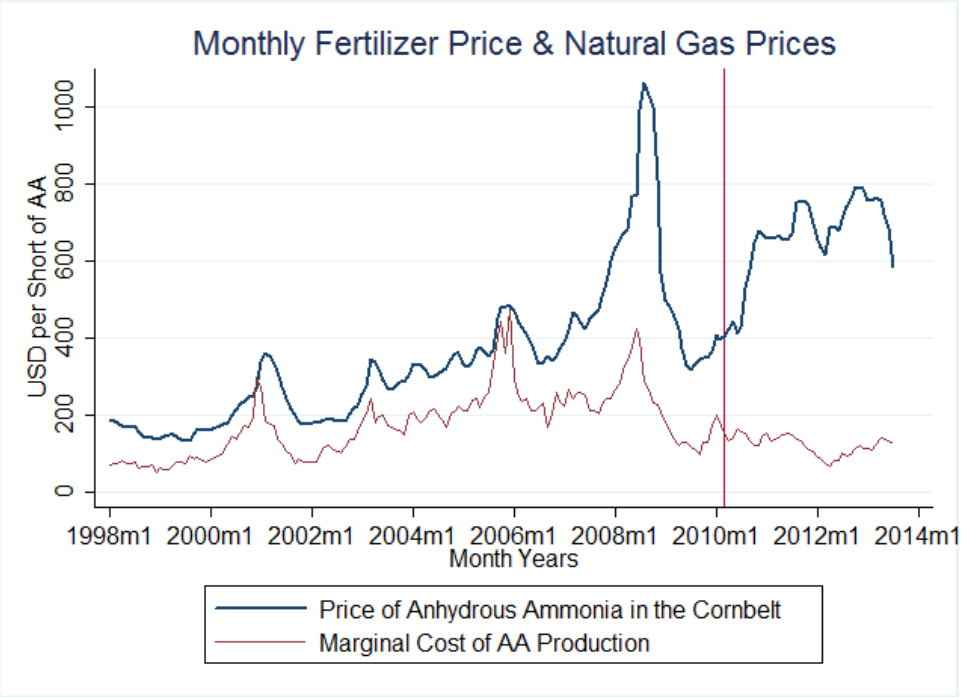

Figure 1: Fertilizer Prices and Marginal Cost.

The merger happens to coincide with a spike in corn future prices. This result is depicted in figure 2. The fact that fertilizer prices follow corn futures during the 2010 shock is consistent with two explanations of why AA prices have decoupled from natural gas prices. The first explanation is the maintained hypothesis, the merger increases market power. The second explanation, high corn prices have spurred on fertilizer demand, causing fertilizer producers to be capacity constrained. Inadequate data periodicity makes it infeasible to directly model production decisions in the SVAR model.

With this in mind, it is only possible to demonstrate graphically that the industry is not capacity constrained. Figure 3 depicts the industry level utilization rates.

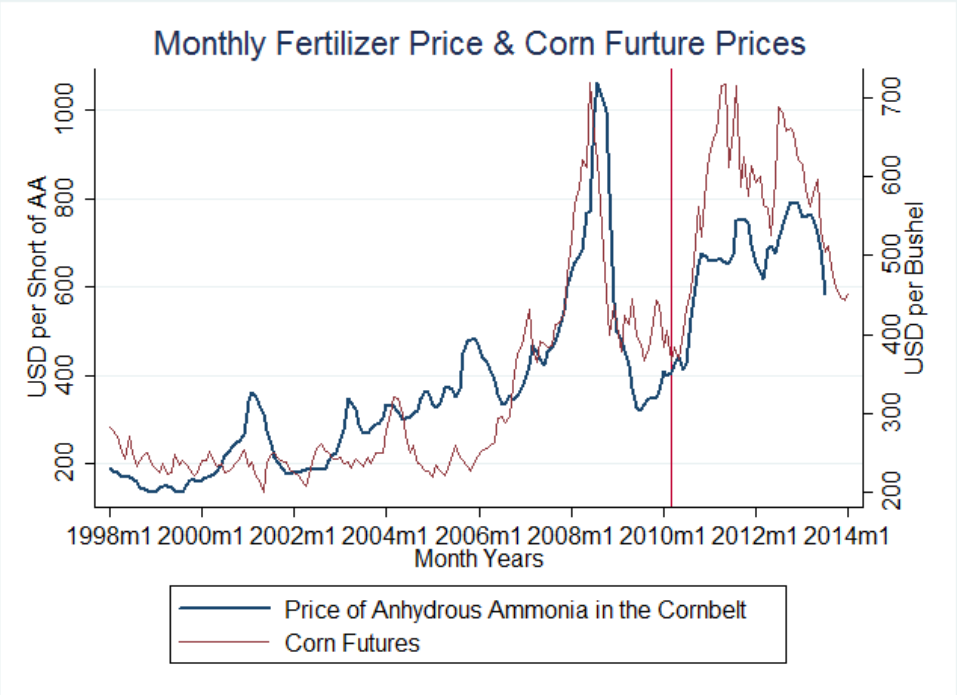

Figure 2: Fertilizer Prices and Corn Futures.

The quarterly utilization rates are calculated by dividing quarterly production by quarterly capacity. Figure 3 clearly shows that utilization do not increase after the 2010 merger. Further, utilization rates are much higher for the spike in corn prices that occurred in 2008. This lends some strength to the idea that the merger did increase market power. The fact that a similar shock in 2010 did not have as large as an effect on utilization rates as the 2008 is suggestive that firms where better able to manage production post-merger.

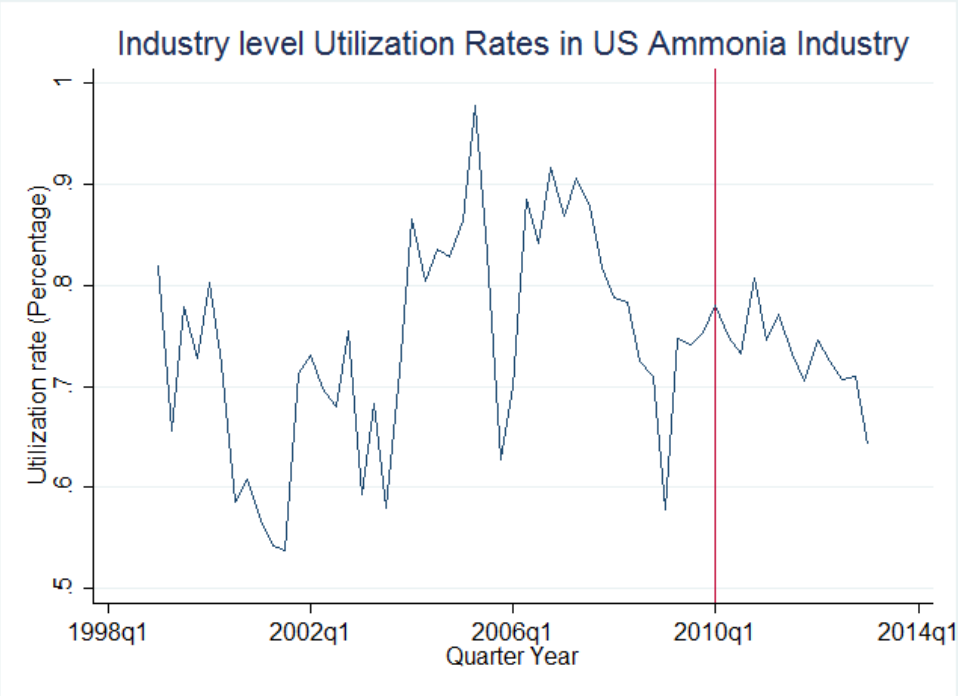

Figure 3: Industry Level Utilization Rates of Anhydrous Ammonia Production

2.1 Merger Literature

Before moving on to the empirical model below, it is important to briefly discuss the existing literature on retrospective merger analysis. This literature generally takes one of two approaches, which will be referred to as the Reduced-Form-Approach and the Structural-Form-Approach.

The Reduced-Form-Approach adopts a difference in difference methodology to analyze how mergers affect retail\wholesale prices. This type of literature generally exploits spatial variation in the impact of a merger to construct treatment and control groups. Examples include, Kim and Signal (1993), Hastings (2004), and Ashenfelter and Hosken (2008). The benefit of this approach is it transparency. The identification of the

effects of a merger only require the presents of a credible control market. Unfortunately, as pointed out by Nevo and Whinston (2010), in the presents of efficient markets such control groups are generally not present. For example, CF and Terra industries sell fertilizer throughout the US and Canada, and therefore, it is infeasible to construct a credible control group. This greatly limits the scope of mergers which can be analyzed by this approach.

The Structural-Form-Approach, as its names suggests, identifies the effects of a merger by using economic theory to impose strong assumptions on the data. Typically such an approach begins by estimating a demand function. Next, a form of market conduct is assumed, such as Bertrand–Nash price-based competition. Finally, industry behavior is simulated with and without the merger. The seminal example of this approach is Nevo (2000). This approach's strength is the fact that it can be applied to a more general class of merger analysis than the Reduced-Form-Approach. Despite this fact, Angrist and Pischke (2010) heavily criticize the Structural-Form-Approach for lacking transparency.

In this paper a structural vector autoregressive model is employed to conduct retrospective merger analysis. This approach to retrospective merger analysis circumvents the weakness of the aforementioned methodology currently used in the literature. Employing this methodology does not require a control group. Further, it

does not require strong structural assumptions and is consequently more transparent than the Structural-Form-Approach.

3 Empirical Model

A structural vector autoregressive model is employed to estimate the impact that the 2010 merger between CF and Terra industries had on fertilizer prices. The SVAR model is defined as follows

$$AY_t = \sum_{i=1}^{12} B_i Y_{t-i} + \Gamma Z_t + U_t, \quad (1)$$

$$Y_t = \begin{bmatrix} NG_t \\ Corn_t \\ AA_t \end{bmatrix}, U_t = \begin{bmatrix} u_{NG,t} \\ u_{Corn,t} \\ u_{AA,t} \end{bmatrix}, \text{and } Z_t = \begin{bmatrix} 1 \\ t \\ D_s \\ D_f \\ D_w \end{bmatrix}.$$

Above, D_s, D_f and D_w, represent dummy variables for summer, fall and winter. In order to identify the contemporaneous coefficients in the above system of equations, restrictions must be placed on the A matrix. The restrictions imposed in the estimation of this model are as follows: contemporaneous shocks to corn ($\alpha_{12} = 0$) and fertilizer ($\alpha_{13} = 0$) prices do not affect natural gas prices, and contemporaneous shocks to fertilizer prices do not affect corn prices ($\alpha_{23} = 0$).

$$A = \begin{bmatrix} 1 & \alpha_{12} & \alpha_{13} \\ \alpha_{21} & 1 & \alpha_{23} \\ \alpha_{31} & \alpha_{32} & 1 \end{bmatrix}, \text{where } \alpha_{12} = \alpha_{13} = \alpha_{23} = 0$$

Clearly the credibility of this methodology is contingent on the fact that these assumptions are true.

3.1 Assumption 1: $\alpha_{12} = 0$

Natural gas is by far the most important input in the production of nitrogen fertilizer. Despite this fact, the nitrogen fertilizer industry consumes less than 1.5% of all natural gas consumed annually in the United States. This small position in the natural gas market makes it infeasible for fertilizer price shocks to have large effects on natural gas prices.

3.2 Assumption 2: $\alpha_{13} = 0$

This assumption is immediately obvious. Fertilizer is the main link by which corn prices would affect natural gas prices.

3.3 Assumption 3: $\alpha_{23} = 0$

Nitrogen fertilizer application for corn fields generally occur in the early spring. Clearly, contemporaneous shocks fertilizer prices will have little effect on corn futures on average. This assumption can be tested. An instrumental variables approach can help disentangle the contemporaneous relationship between AA prices and corn futures. Clearly, natural gas prices can serve as an instrument to help understand how fertilizer prices affect corn futures. Conversely, gasoline or ethanol prices can serve as an instrument to help understand how corn futures affect fertilizer prices.

3.4 Counterfactual analysis

After estimating the SVAR model proposed above, a counterfactual price series of fertilizer prices can be generated in the absence of the merger. This is accomplished

by imposing the assumption that $\hat{u}_{AA,t} = 0$, while setting the remaining structural shocks to their estimated values. Given these assumption, counterfactual AA prices are obtained by forecasting prices from March 2010, the beginning of the merger, onward.

$$\begin{bmatrix} NG_t^{CF} \\ Corn_t^{CF} \\ AA_t^{CF} \end{bmatrix} = \hat{A}^{-1} \sum_{i=1}^{12} \widehat{B}_i \begin{bmatrix} NG_{t-i}^{CF} \\ Corn_{t-i}^{CF} \\ AA_{t-i}^{CF} \end{bmatrix} + \hat{A}^{-1} \hat{\Gamma} Z_t + \hat{A}^{-1} \begin{bmatrix} \hat{u}_{NG,t} \\ \hat{u}_{Corn,t} \\ 0 \end{bmatrix}$$

4 Data

Fertilizer prices are obtained from Green Markets, which collects weekly wholesale prices on a myriad of fertilizers prices throughout the US and the rest of the world. Natural gas prices are Henry Hub spot prices collected by the U.S. Energy Information Administration. Finally corn futures are average settlement prices of future contracts traded on the Chicago Board of Trade. All data has a monthly periodicity.

5 Results

Before estimation, all price series are tested to determine if they are non-stationary. This is accomplished by conducting the Augmented Dickey Fuller test on all price series. At the 5% significance level, the null hypothesis of non-stationarity can only be rejected for the fertilizer price series. This implies that fertilizer prices are stationary while both natural gas prices and corn futures are non-stationary. A Johansen test is conducted on natural gas prices and corn futures. The maximum eigenvalue statistics (of rank 0) are smaller than the critical value at the 5% significance level, implying that we fail to reject the null hypothesis of no cointegration.

Before estimating equation 1, we first difference the data. This transformation insures that all price series are integrated of degree 0. Due to the lack of cointegration, an error correction term is excluded from the model. Equation 1 is estimated in levels as well as a log-log specification. While the results are similar across the different specifications, the results from the log-log specification are reported.

5.1 Impulse Response Functions

The impulse response functions are reported in figure 4. This figure reports results for the log-log specification of equation 1. The below results conform to a priori expectations. Shocks to corn and fertilizer prices (denoted as D.l_AA_price in the figure below) have no effect on natural gas prices. Additionally, shocks to natural gas prices do not affect corn futures. Conversely, shocks to corn futures as well as natural gas prices affect fertilizer prices. However, it is hard to discern these effects from figure 4. For a more detailed depiction, see figure 4.1 and 4.2 in the appendix. Notice that AA prices have a large impact on corn futures. While we expect nitrogen fertilizer prices to affect corn prices, the magnitude of the effect is surprising. This finding could be the result of omitted variables. To test whether this is the case, additional variables should be included in the model. McPhail et al (2012) outlines several key variables that effect corn prices which could be integrated within the SVAR model.

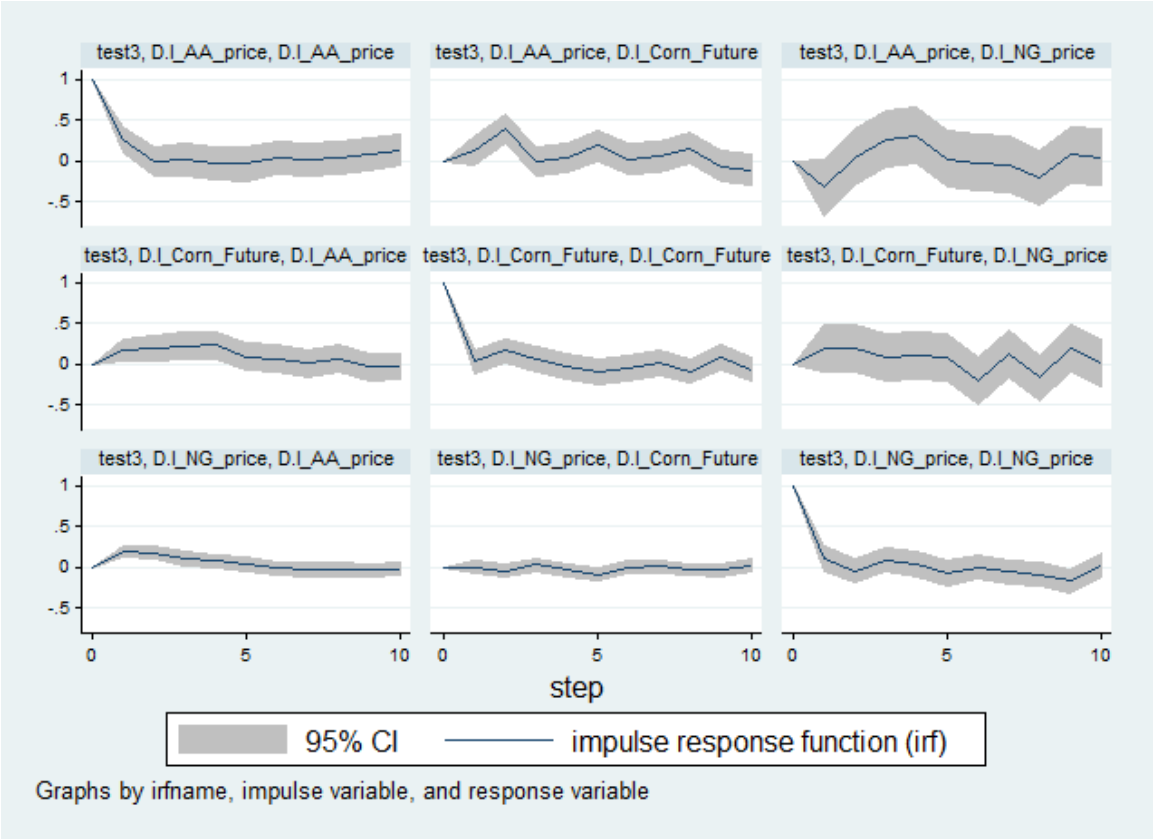

Figure 4: Impulse Response Functions

5.2 Counterfactual Analysis

The counterfactual results are depicted in Figure 5. Clearly, the merger had a very large effect on fertilizer prices. The counterfactual analysis suggests that the merger caused fertilizer prices to rise by 75%. In the absence of the merger, however, fertilize prices would remain high. Despite facing the lowest natural gas prices in 10 years, counterfactual fertilizer prices are still higher than any point in the past other than the 2007-2008 commodity boom. This fact is due to the presents of high corn prices in 2010.

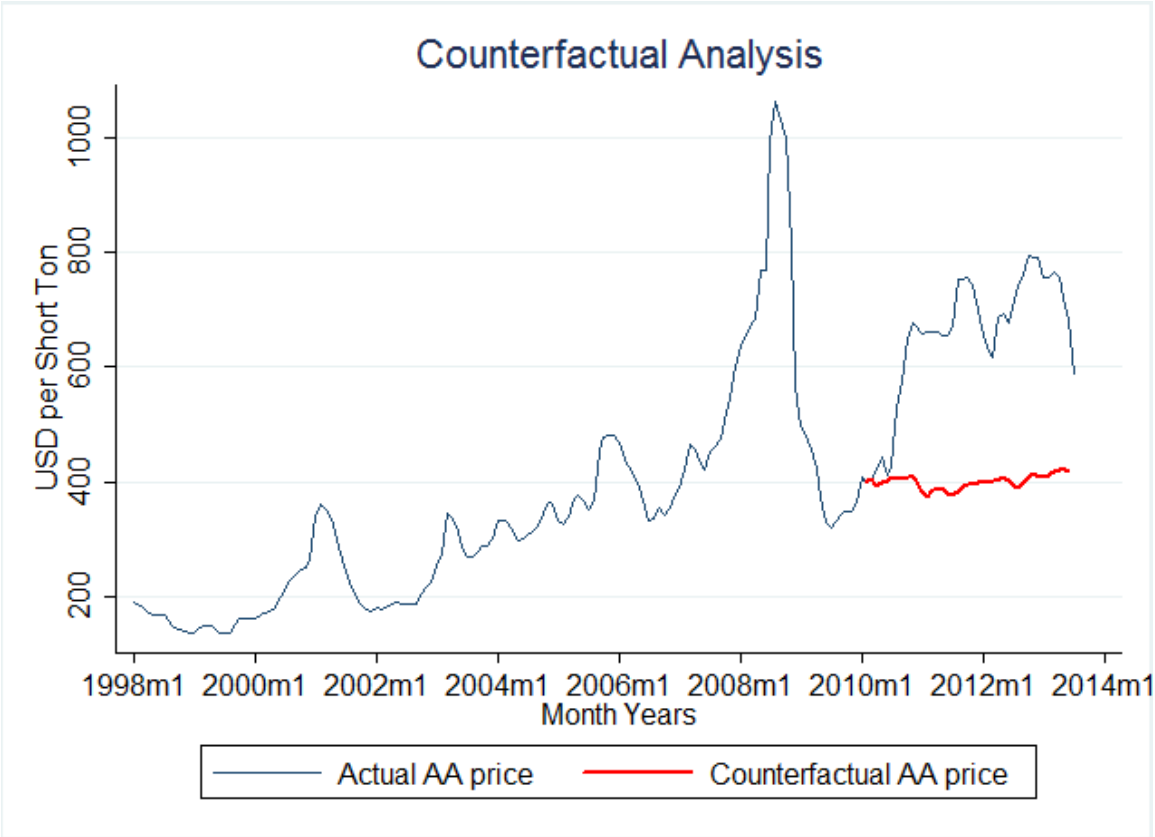

Figure 5: Counterfactual Analysis

6 Conclusion

In this paper, a time series approach was employed to determine the impact that the 2010 merger between CF industries and Terra industries had on fertilizer prices. The counterfactual fertilizer price series generated by the Structural Vector Autoregressive model suggests that the merger increased fertilizer prices by 75%.

Additional work on this topic will strive towards expanding the credibility of the findings. We feel that four additions in particular will serve to strengthen the results:

1) Using instrumental variables to verify the that $\alpha_{23} = 0$.

2) Include variables present in McPhail et a. (2012) to better model the movement of corn prices. This will help control for any potential omitted variable bias.
3) Estimate a historical decomposition of the SVAR model. A historical decomposition will facilitate a more thorough understanding of how well corn and natural gas prices explain fertilizer prices.
4) Conduct the counterfactual analysis with a density forecast as opposed to a point forecast. This will allow for a better understanding of the precision of the counterfactual analysis.

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Appendix

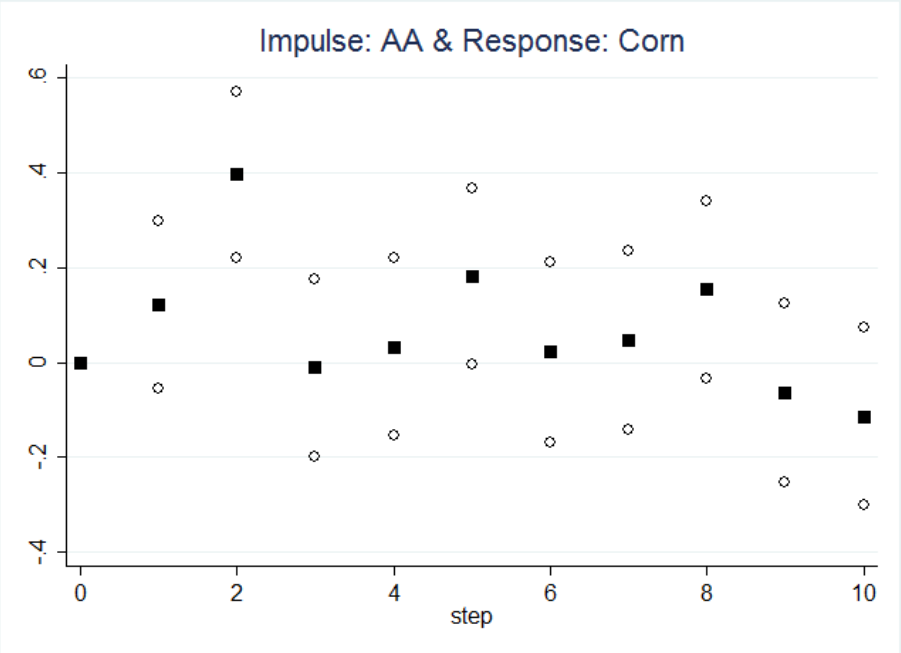

Figure 4.1: I

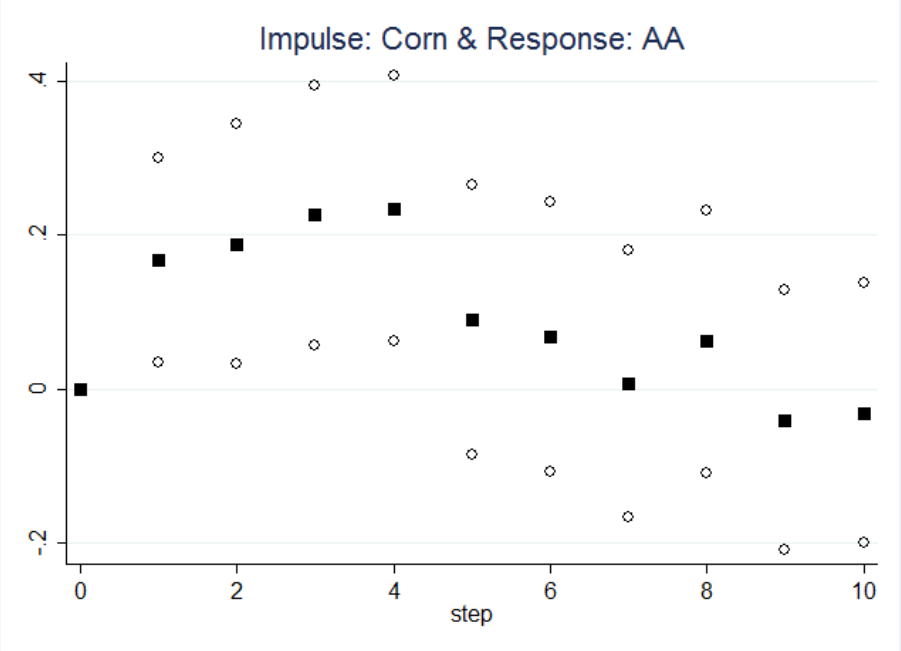

Figure 4.2:

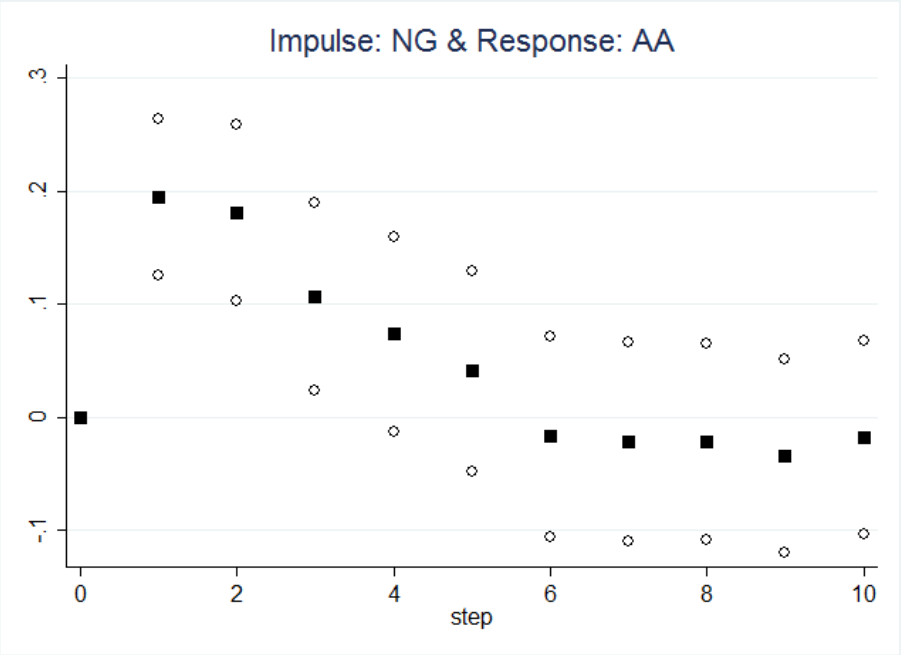

Figure 4.3:

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