Not All Energy Shocks Are Alike: Disentangling Shocks in the U.S. Fertilizer Market

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Introduction

The study of causal and dynamic relationships between energy and agricultural markets has been a topic of great interest in recent years. Evidence suggests that energy and agricultural commodity prices have become more closely related in recent years, particularly since the increased reliance on biofuels in the U.S. after the passage of the Energy Policy Act of 2005 (Mallory et al., 2012). Most of the current research has been focused on studying the impact of the biofuels boom, particularly related to ethanol, on food crops and energy (crude oil and gasoline) prices. However, the analysis of other potential channels of price transmission between energy and agricultural markets, such as in the case of nitrogen fertilizers used as a main input in food crop production, has received little attention among the research community. Because natural gas is the main ingredient used in nitrogen fertilizer production, one would expect that changes in the natural gas market may also affect production costs and the selling price of nitrogen fertilizers.

Fertilizers are one of the major production factors utilized in agricultural production, particularly in grain crops. In recent years, the steadily growing global demand for grain crops has generated higher crop prices and increased demand for fertilizers (Ruder and Bennion, 2013). Among the three major types of fertilizer (nitrogen, phosphate and potash), nitrogen fertilizers are the largest consumed in the U.S. In 2006, nitrogen accounted for 56.6 percent of the 21.3 million tons of chemical fertilizer nutrients used by U.S. agriculture. From 1960 to 2005, the usage of nitrogen fertilizers increased from 2.7 to 12.3 million tons. This increase is one of the main reasons behind the increased crop yields in the U.S. (Huang, 2007).

In recent years, the U.S. natural gas market underwent major transformations due to the development of new extraction techniques such as hydraulic fracturing and horizontal drilling (Brown Yucel, 2013). High oil and gas prices made it economically feasible to introduce these technologies, which in turn substantially increased U.S. natural gas and oil production. However, as natural gas prices declined over the past 10 years, fertilizer prices have reached record highs in the late 2000's, a trend that has been maintained steady (Beckmand and Riche, 2015). Conversely, the increase in ethanol production, particularly from corn, following the biofuels boom has boosted the demand for nitrogen fertilizers. About 46 percent of total nitrogen used in recent years has been attributed to the production of corn (U.S. Department of Agriculture, Economic Research Service, 2013). Therefore, an important question that emerges is how recent changes in energy markets, particularly the shale boom experienced by the natural gas market and the surge in ethanol production from corn, have affected nitrogen fertilizer prices.

The economics literature on the fertilizer industry and its relationship with natural gas markets is very sparse, and only a handful of papers have attempted to shed a light on how recent changes affecting energy markets affect supply, demand and prices in this industry. For example, Beckmand and Riche (2015) examined price linkages between natural gas, corn and fertilizer markets. They found that before 2008, ammonia prices had a strong relationship with natural gas prices. However, this link has been weakening post-2008. It appears that other factors, mostly linked to the demand side, are driving the behavior of fertilizer prices. Thus, indicating that important changes in the structure of the fertilizer market have occurred since the shale revolution and biofuels boom.

The typical approach used by researches to analyze price dynamics between markets is the estimation of structural vector autoregression (VAR) models where structural shocks are extrapolated using different identification approaches, such as Choleski decomposition of the reduced form variance-covariance matrix. However, one of the main criticisms of classical VARs is that they assume parameter stability across time, regardless of whether the true relationship between variables changes over time. This caveat is particularly relevant in the analysis of fertilizer market dynamics because of the recent changes experienced in energy markets. To address this issue, time varying parameter (TVP) VAR models estimated using Bayesian methods were introduced in the literature. The advantage of these models is that they allow to capture the changing nature of the relationship between economic time series (Canova, 2007).

The objective of this study is to conduct a comprehensive analysis on what factors drive the price of nitrogen fertilizer in the US. To answer this question, we estimate a TVP-VAR model using annual data from 1961 to 2013 on the following variables: natural gas price, and fertilizer production, consumption and price. Natural gas price is included to account for changes in input costs. Similarly, fertilizer production and consumption are included to capture industry specific supply and demand shocks. In particular, demand shocks are expected to capture the effect of the increased demand in fertilizers caused by an increase in grain production. Using the method proposed in this study, we are able to disentangle the effect of each shock on fertilizer prices through time.

Results from this study have important implications for fertilizer and agricultural markets. First, understanding how natural gas market shocks affect the fertilizer market is important for modeling the dynamics in agricultural markets because fertilizer is a major input in the crop production. Second, by understanding what factors determine fertilizer prices, U.S. farmers will be able to make better informed decisions of whether to hedge against future increases in the price of fertilizer. Third, our results allow us to disentangle supply and demand shocks, for ultimately determine how these to forces have driven fertilizer prices through time.

Results

U.S. annual data from 1961 to 2013 corresponding to natural gas prices, nitrogen fertilizer production, consumption (use) and price are used in this analysis.[1] Nominal natural gas prices are Henry Hub spot prices obtained from the U.S. Energy Information Administration (EIA), and were converted to real using the consumer price index. Fertilizer production and consumption data are obtained from the Food and Agriculture Organization (FAO, 2014). The nitrogen fertilizer price is represented by the real producer price index of nitrogen fertilizer manufacturing, and was collected from the Bureau of Labor Statistics (BLS, 2014).

To evaluate dynamic relationships between variables, impulse response functions were computed using results from the estimation of the TVP-VAR model. Figures 1, 2 and 3 and 4 present three dimensional (3D) responses of each variable in the system following a one-time standard deviation shock to each variable, through time. Each figure contains 4 different 3D plots, representing the responses of production, consumption, real price of fertilizer and real price of natural gas following a one standard deviation shock to a particular variable on a 5-year horizon. In each plot, the magnitude of reaction is measured by the color-coded bar next to it. The lateral axis (not observed), corresponds to the period from 1988 to 2013. This axis allows us to compare the responses of each variable through time.

Impulse responses of each variable in the system following a shock to nitrogen fertilizer production through time, are presented in figure 1. Interestingly, the real price of fertilizer first reacts positively to this shock only on earlier years. In later years, fertilizer prices are affected negatively, as expected. Another interesting finding is that the real price of natural gas displays a positive reaction following a shock to fertilizer production. This trend has been maintained

[1] Fertilizer use data is only available at an annual frequency, thus limiting the possibility of using higher data frequency in our analysis.

through time. Consistent with the expectations, as the production of fertilizer increases, the demand for natural gas increases, causing an increase in natural gas prices.

Figure 2 presents impulse responses of each variable in the system following a shock to nitrogen fertilizer consumption, through time. Fertilizer production first reacts negatively following a shock to fertilizer consumption. Then, production spikes up within the first year after the shock. This increase in fertilizer production is larger in recent years, indicating that fertilizer producers are more responsive to changes in fertilizer demand. The effect of consumption on the real price of fertilizer is first positive, as expected, and then it gradually becomes negative through the 5-year horizon. In earlier years, however, demand shocks have a larger effect on fertilizer prices and take a longer time to die out. Furthermore, the real price of natural gas have a positive reaction following a shock to fertilizer consumption. However, in recent years the magnitude of reaction has decreased.

Variable responses following shocks to the real price of fertilizer are presented in figure 3. The response of fertilizer production following this shock indicates that fertilizer producers are not able to react to an increase in fertilizer price immediately, at least in earlier years. That is, production is only able to increase two years after the shock. In later years, however, fertilizer production does not react, or has a slightly negative response, to shocks on fertilizer price. On the other hand, fertilizer price shocks first decreases fertilizer consumption, as expected. However, this shock is short-lived. About two years after the fertilizer price shock, consumption increases. This trend has been maintained through time.

Finally, figure 4 presents impulse responses following a shock to the real price of natural gas. Fertilizer production and price react first negatively following this shock, and then this shock dies out in subsequent periods along the 5-year horizon. On the contrary, fertilizer consumption has a positive reaction following a natural gas price shock.

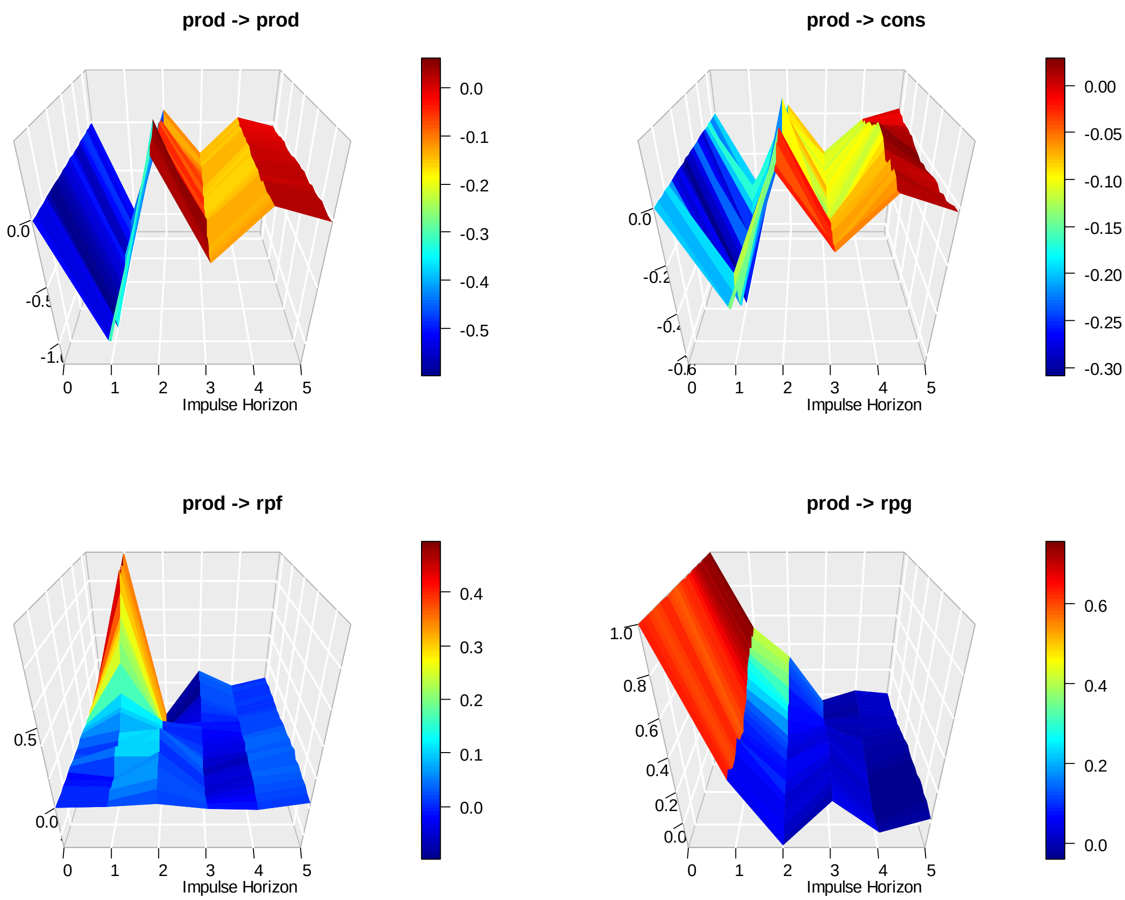

Figure 1. Impulse Responses of Fertilizer Production, Consumption, Real Price of Fertilizer and Real Price of Natural Gas following a One Standard Deviation Shock to Fertilizer Production

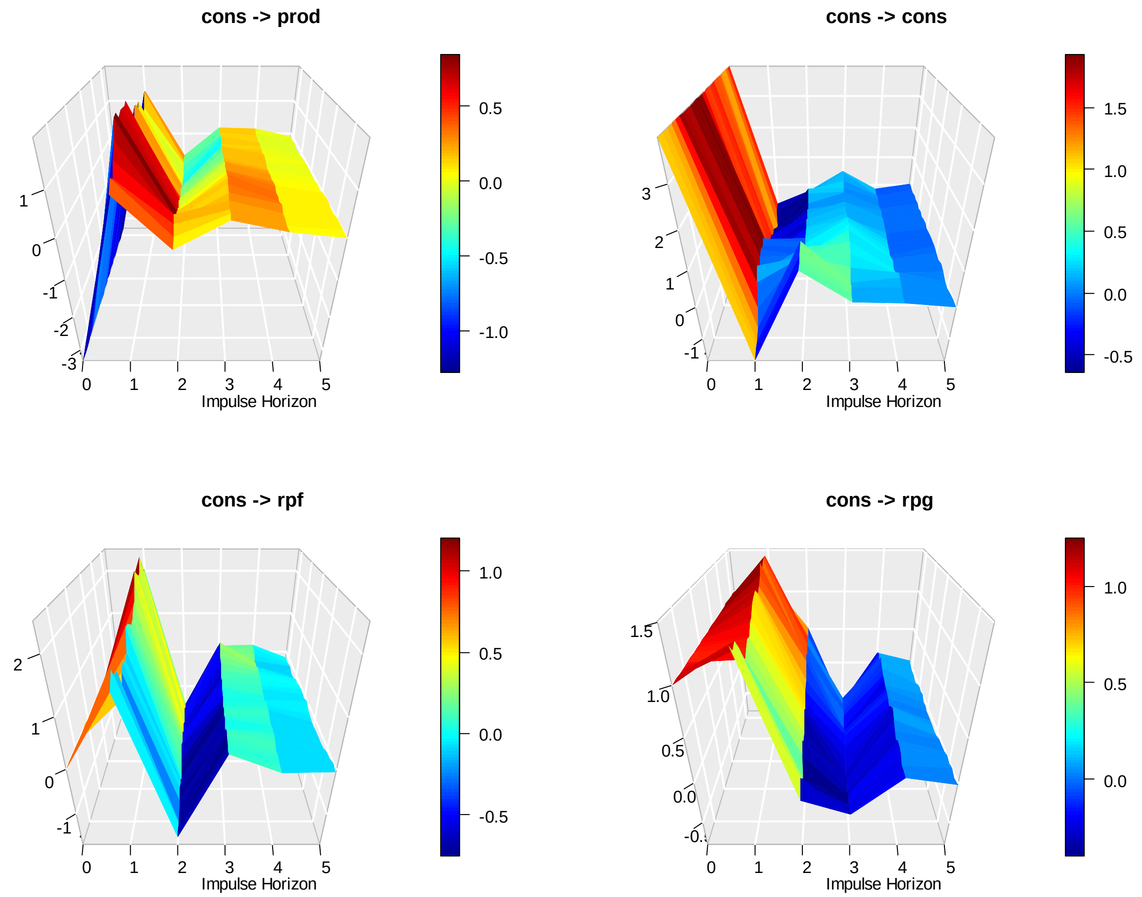

Figure 1. Impulse Responses of Fertilizer Production, Consumption, Real Price of Fertilizer and Real Price of Natural Gas following a One Standard Deviation Shock to Fertilizer Consumption

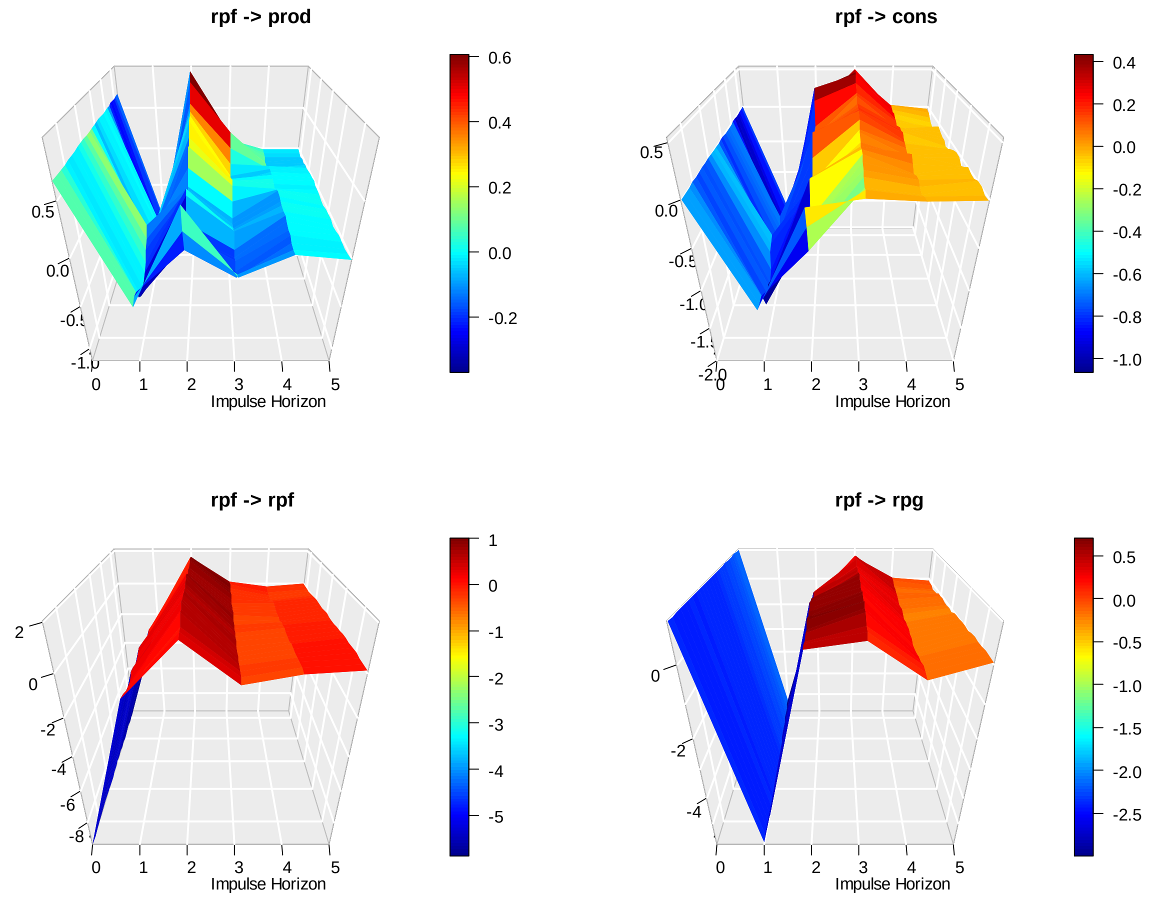

Figure 1. Impulse Responses of Fertilizer Production, Consumption, Real Price of Fertilizer and Real Price of Natural Gas following a One Standard Deviation Shock to Real Price of Fertilizer

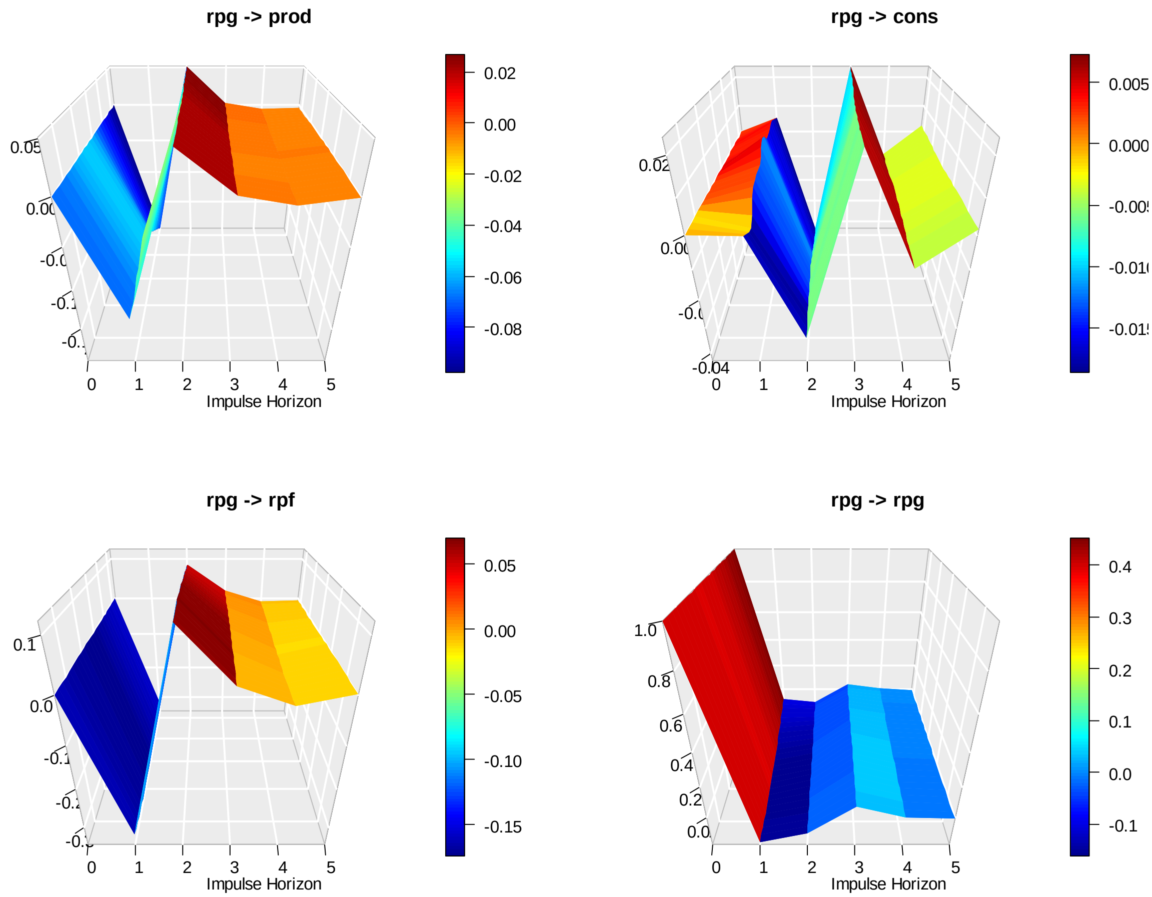

Figure 1. Impulse Responses of Fertilizer Production, Consumption, Real Price of Fertilizer and Real Price of Natural Gas following a One Standard Deviation Shock to Real Price of Natural Gas