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Another perspective on gasoline price responses to crude oil price changes☆

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ABSTRACT

The effects of oil price volatility on the responses of gasoline prices to oil price shocks have received little attention in discussions on the relationship between the prices of crude oil and gasoline. In this paper we consider such effects by using a bivariate structural vector autoregression which is modified to accommodate GARCH-in-mean errors. Our measure of oil price volatility is the conditional variance of the oil price–change forecast error. We isolate the effects of volatility in the price of oil on the price of gasoline and employ simulation methods to calculate nonlinear impulse response functions (NIRFs) to trace any asymmetric effects of independent oil price shocks on the conditional means of gasoline prices. We test whether the relationship between the prices of crude oil and gasoline is symmetric using tests of the null hypothesis of symmetric impulse responses. Based on monthly U.S. data over the period from 1978:1 to 2014:11, our empirical results show that gasoline prices respond asymmetrically to positive and negative oil price shocks. We also find that oil price volatility has a positive effect on the price of gasoline and it contributes to the asymmetries in the transmission of oil price shocks.

1. Introduction

Questions regarding the relationship between the prices of crude oil and gasoline are interesting empirical issues in economics. A large number of theoretical studies have attempted to investigate this relationship and found that gasoline prices respond more quickly to increases in crude oil prices than to decreases, showing an asymmetric relationship between gasoline price responses and crude oil price shocks. These papers consider a variety of explanations, including adjustment of production and inventory cost of crude oil, menu cost, oligopolistic coordination theory, and the search theory. For a review of this literature, see Borenstein et al. (1997); Peltzman (2000); Johnson (2002), and Davis and Hamilton (2004).

Several empirical studies have also investigated the pricing behavior in the gasoline market. However, these studies often provide conflicting evidence on the asymmetric relationship between the prices of crude oil and gasoline. Douglas and Herrera (2010, 2014), for example, use an autoregressive conditional binomial (ACB) model to examine stickiness in wholesale and retail gasoline prices and find evidence of asymmetry in daily data. Borenstein et al. (1997) also find strong evidence of asymmetry in the US market in different stages in the production and distribution of gasoline, from the refineries to the city pumps, using weekly and biweekly data from 1986 to 1992. Bachmeier and Griffin (2003), on the other hand, report no evidence of asymmetry in the US wholesale gasoline market for daily spot gasoline and crude oil price data, over the period 1985–1998. In a recent paper, Venditti (2010) also reports no systematic evidence of asymmetry for the US as well as Euro areas over 1999–2009, using non linear impulse response functions with asymmetric price adjustment, as opposed to the traditional linear impulse response functions used in previous studies.

This paper reconciles these earlier empirical results by first jointly modelling volatility in the changes in the prices of crude oil and gasoline, and then investigating the responses of gasoline price changes to oil price shocks after allowing the effects of oil price volatility. In doing so, we use an extremely general bivariate framework in which a structural vector autoregression is modified to accommodate GARCH (1,1)-in-mean errors, as detailed in Engle and Kroner (1995) and Elder (2004). Our measure of oil price change volatility is the conditional variance of the oil price change forecast error. We isolate the effects of oil price change volatility on gasoline price changes and, following Koop et al. (1996) and Kilian and Vigfusson (2011a), we employ simulation methods to calculate nonlinear impulse response functions (NIRFs) to trace any asymmetric effects of independent oil price shocks (positive and negative) on the conditional means of the gasoline price changes. We then conduct a NIRFs based direct test of the null hypothesis of symmetric impulse responses to positive and negative oil price shocks.

In several ways, this paper makes contribution to the literature on the effects of oil price shocks on the price of gasoline. First, in investigating such effects, very few studies have considered our approach. Radchenko (2005), for example, modelled oil price volatility using a univariate GARCH (1,1) model, introduced it into a vector autoregression (VAR) system to estimate various gasoline price asymmetry measures, and, then, set another VAR system in each of these asymmetry measures with oil price volatility. Radchenko (2005)

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found that the degree of asymmetry in gasoline prices declines with an increase in oil price volatility. The Radchenko (2005) approach, however, is ad-hoc and uses censored endogenous variables that make the parameter estimates inconsistent, as suggested in Kilian and Vigfusson (2011a). Moreover, his empirical model is subject to the generated regressor problem, described by Pagan (1984), as it involves several steps in estimation. In contrast, in this paper we examine the relationship between the prices of crude oil and gasoline in a well parameterized flexible framework, that simultaneously estimates the parameters of interest in an internally consistent fashion, thus avoiding the problem of generated regressors.

Second, a number of studies have already investigated asymmetric effects of oil price shocks on the price of gasoline using daily, weekly, or bi-weekly data. These high frequency results, however, may not always hold at monthly frequency and, hence, in this paper we use monthly data to examine the validity of the earlier results to data frequency as well as to model specification.

Third, in calculating the responses of the price of gasoline to crude oil price shocks, we take into account the nonlinearity of the model, induced by oil price volatility, the sign and size of the shock, and the history of the system. Previous works have ignored such nonlinearity and, therefore, their findings regarding the asymmetric effects of oil price shocks on the price of gasoline is highly questionable. In this paper, we follow Koop et al. (1996) and use the correct forms of impulse response functions to analyze the responses of gasoline prices to oil price shocks.

Finally, in the context of the relationship between the prices of crude oil and gasoline, Chang and Serletis (2016) investigate the asymmetric effects of oil price shocks on the price of gasoline, using a bivariate GARCH (1,1)-in-Mean structural VAR model, which is similar to the empirical model used in this study. However, this paper is independently developed and different from Chang and Serletis (2016) on an important aspect. We follow Kilian and Vigfusson (2011a) to employ a direct test of the null hypothesis of symmetric impulse responses to positive and negative oil price shocks of the same magnitude. To the best of our knowledge, no other studies including Chang and Serletis (2016) have applied such tests based on a nonlinear volatility model that we use in this study.

We find that our bivariate GARCH(1,1)-in-Mean SVAR model embodies a reasonable description of the monthly U.S. data on crude oil and gasoline price changes, over a sample period from 1978:1 to 2014:11. Based on this updated sample that includes the increased volatility in oil prices since 2008 and the Great Recession, we present evidence that increased volatility about the change in the real price of oil is associated with a higher level of gasoline prices. Nonlinear impulse response experiments highlight the asymmetric effects of positive and negative shocks in the change in the real price of oil on real gasoline price changes. In particular, we find that a positive shock increases the price of gasoline by 11% in two months, compared to a negative shock that only reduces the price of gasoline by only 1% in the same period. The impulse response based symmetry test provides further evidence in favour of this asymmetry, as we reject the null hypothesis of symmetric impulse responses to positive and negative oil price shocks. Our empirical results suggest that oil price volatility contributes to the asymmetries in the transmission of oil price shocks to gasoline prices.

The paper is organized as follows. Section 2 presents the data and Section 3 provides a brief description of the bivariate GARCH(1,1)-in-Mean SVAR model. Sections 4 and 5 assess the appropriateness of the econometric methodology by various information criteria and present and discuss the empirical results. In Section 6, we employ tests of the null hypothesis of symmetric impulse responses, recently introduced by Kilian and Vigfusson (2011a), to investigate whether the relationship between crude oil and gasoline prices is asymmetric. Section 7 provides explanation behind asymmetry based on transmission of oil price shocks to the price of gasoline. Section 8 checks the robustness of our results and the final section concludes the paper.

2. The data

We use monthly data for the United States, from the Energy Information Administration (EIA) database, on two variables: the real price of oil (oil_t) and the real price of gasoline (gas_t). Our monthly series on the prices of oil and gasoline span over the period from 1978:1 to 2014:11, since EIA data on gasoline prices, which includes all types of gasoline (leaded and unleaded ones), are available only from 1978. We calculate the real price of gasoline by dividing the U.S. City Average Nominal Retail Gasoline Price by the CPI. In the same way, we use the refiner's imported acquisition cost (RAC) as the nominal price of oil and divide it by the consumer price index (CPI) to obtain the real price of oil.

Regarding our choice of the RAC of crude oil, as Kilian and Vigfusson (2011b) put it, "leading candidates for the oil price series include the price of West Texas Intermediate crude oil, the U.S. producer price of crude oil, and the U.S. refiners' acquisition cost available for imported crude oil, for domestic crude oil, and for a composite of domestic and imported crude oil. There is no general consensus on which price of

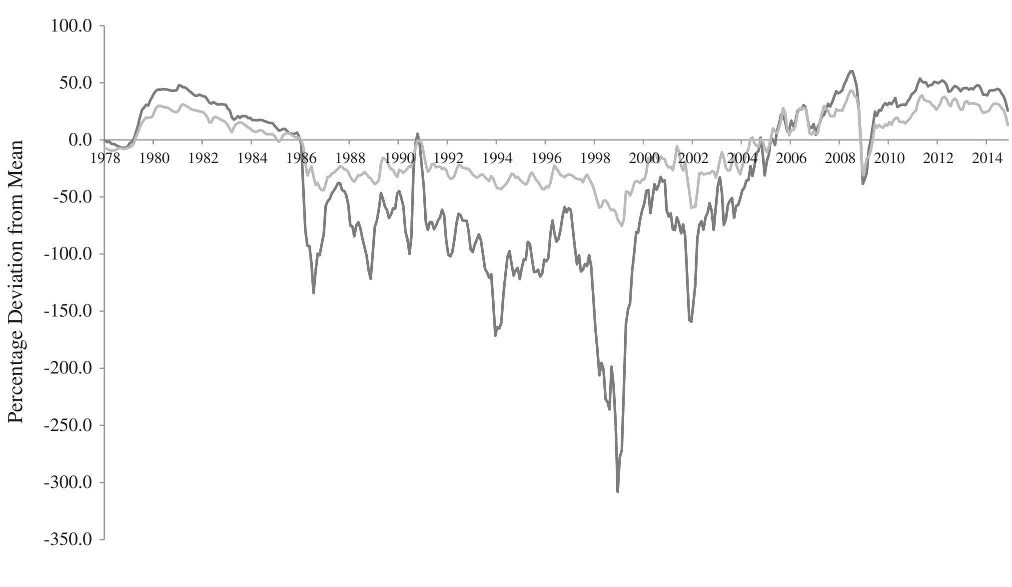

Fig. 1. Real Price of Crude oil and Real Price of Gasoline, 1978:1 to 2014:11.