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Inventories and upstream gasoline price dynamics ☆

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ABSTRACT

This paper sheds new light on the asymmetric dynamics in upstream U.S. gasoline prices. The model is based on Pindyck's inventory model of commodity price dynamics. We show that asymmetry in gasoline price dynamics is caused by changes in the net marginal convenience yield: higher costs of marketing and storage lead to rising gasoline prices, whereas a drop in these costs lowers gasoline prices. The former effect is stronger. This indicates asymmetric dynamics. We also analyze the asymmetry across the sample by analyzing recursive and rolling regressions.

1. Introduction

In June 14, 2001 when the crude oil price was 69 cents per gallon, John Cook (Director of the Petroleum Division in the U.S. Energy Information Administration's Office of Oil and Gas) testified before the Committee on Government Reform of the U.S. House of Representatives. He argued that "…Low stocks set the stage for gasoline price increases this spring. … This ongoing tightness has been a key factor in maintaining both low crude and product inventories since then…". He expects prices to continue to decline in the summer of 2001 because production in the U.S. increased significantly. However, gasoline markets remain exposed to volatility because of low global oil inventories (Energy Information Administration, 2001). Crude oil prices indeed dropped and hit a low on November 15, 2001 of 41.7 cents per gallon. Crude oil prices started to rise again in 2002, and broke the 100 cents per gallon barrier for the first time on May 24, 2004. On May 16, 2008 one gallon of crude oil costs 301 cents. On June 25 that year Guy Caruso testified before the Committee on Appropriations of the U.S. House of Representatives that "…the current very tight oil market balances and the possibility of further oil supply disruptions are causing prices to rise to unprecedented highs…". (Energy Information Administration, 2008a). The peak of 346 cents per gallon was reached on July 11, 2008, but only five months later the price of a gallon of crude oil dropped to only 72 cents. After that the crude oil price rose again steadily to 263 cents per gallon in May 2011. Gasoline prices followed more or less the same pattern, but the reaction of gasoline prices to changes in crude oil prices is not necessarily symmetric (see Frey and Manera, 2007 for a review).

These facts show that fluctuations in crude oil prices and gasoline prices are large and volatile. These fluctuations are primarily driven by demand and supply shocks, and by stock levels. This paper examines the role of inventories in a framework that has been used extensively to addresses the question of a systematic tendency for gasoline prices to respond more rapidly to increases in crude oil prices than to decreases in crude oil prices (the so-called *rockets-and-feathers* hypothesis). Understanding gasoline price dynamics and the role of inventories in that process may help to improve to forecast prices of assets that are contingent on oil. Recent examples of this literature are Wu and McCallum (2005), Knetsch (2007) and Alquist and Kilian (2010).

In this paper we examine the role of inventories and volatility in crude oil markets using daily U.S. crude oil prices and regular upstream gasoline prices for the period November 1987 until March 2010. We use the standard two-step error correction estimation procedure and take account of volatility clustering and heavy tails (excess kurtosis) in the

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distribution of crude oil and gasoline price data. We find that marketing and storage costs affect gasoline prices asymmetrically. In the empirical literature so far this explanation is not considered. We also show that the asymmetry emerges after June 1998 when oil prices started to rise.

Our paper differs from other papers by studying the role of inventories and volatility. Moreover, we test for possible structural breaks, and we carefully test our specification. We argue that it is important to account for volatility clustering. Finally, we analyze how asymmetry develops across the sample by carrying out recursive and rolling regressions.

The outline of the paper is as follows. In Section 2 we discuss the related literature. Section 3 explains the inventory model that serves as the foundation of the empirical model presented in Section 4. This section emphasis the dynamics of gasoline prices focusing on persistence, volatility, and asymmetry. In Section 5 we present the data we use in the empirical analysis. We also analyze the data by addressing issues like stationarity, cointegration and breaks in the series. Section 6 describes the methodology and presents the estimation results. We conclude that asymmetric effects due to inventories do exist. We also present interval estimates for different sample sizes and sample periods by means of recursive and rolling regressions. Finally, we illustrate the results with an impulse response analysis. Section 7 summarizes the main conclusion of the paper.

2. Literature

The literature on the asymmetric reaction of gasoline prices to changes in the price of crude oil argues that the results depend on the stage of the production–distribution chain. Not only do the results differ across the production–distribution chain, also the explanation of gasoline price dynamics and the asymmetric effects differs for the upstream stage and the downstream stage (see Borenstein et al., 1997; Galeotti et al., 2003). For a review we refer to Meyer and Von Cramon-Taubadel (2004). Other references are Brown and Yücel (2000), Peltzman (2000), and Johnson (2002).

What are these stages? Crude oil is refined and the gasoline is distributed to gas filling stations via city terminals. This is the upstream stage on which this paper focuses. Gasoline is distributed downstream to gasoline filling stations either directly by the refiners or through middlemen. For each chain there are different theoretical explanations for the dynamics of gasoline prices. A popular explanation for upstream price dynamics is based on the inventory model (see Borenstein and Shepard, 2002; Pindyck, 2004). Central in these models is the convenience yield which is defined as the benefit to inventory holders of keeping inventories in periods of scarce supplies (Kocagil, 2004). Considine and Larson (2001) suggest that convenience yields and risk premium are important elements when crude oil spot prices exceed future crude oil prices (crude oil backwardness, see also Chiou Wei and Zhu, 2006). These backwardations are associated with greater uncertainty (Litzenberger and Rabinowitz, 1995). Moreover, according to Alquist and Kilian (2010) the convenience yield can explain the variability of future prices about the spot price. This already is exploited by Knetsch (2007) to forecast the price of crude oil. French (2005) and Dincerler et al. (2005) analyze the impact of convenience yields on price dynamics. French (2005) suggests that the price response to changes in the convenience yield is nonlinear. Dincerler et al. (2005) claim to have evidence that the convenience yield declines with the level of inventories which introduces mean reversion (see Considine and Larson, 2001).

Borenstein and Shepard (2002) present a model with costly adjustment of production and costly inventory to generate dynamics. If transaction prices equal market-clearing prices, adjustment costs generate lags. This implies that lagged adjustment of gasoline prices requires sticky production and the net marginal convenience yield declining with the level of inventory and increasing with sales. This will be explained in more detail in Section 3. A higher level of inventory reduces distribution costs. Higher sales increase these costs. Market power in these models results in slower adjustment of prices to cost changes, both up and down: higher margins leads to slower adjustment (see Borenstein and Shepard, 2002; Borenstein et al., 1997). We do not focus on market power, but we model the trade-off between selling out of inventory versus production.

Galeotti et al. (2003) hint at the importance of increases in volatility in international gasoline markets without explicitly taking this into account. Also Pindyck (2004) and Radchenko (2005) stress the importance of volatility in crude oil markets for understanding short-run market dynamics. Price volatility may be caused by low crude oil stock levels that were on a downward trend since the beginning of 1995 (Energy Information Administration, 1996) and hit a low early 2004 (Energy Information Administration, 2008b). Low crude oil stocks drive crude oil prices up and can also lead to gasoline supply problems. Radchenko(2005) analyses the effect of volatility in oil prices on asymmetry between crude oil prices and retail gasoline prices using weekly data for the period March 1991 until February 2003. Contrary to Galeotti et al. (2003), he argues that higher volatility reduces the asymmetric response of changes in gasoline prices to changes in crude oil prices.

3. Model

This section briefly discusses the inventory model of Pindyck (2004) which is related to that of Borenstein and Shepard (2002). The main innovation of Pindyck (2004) is the specification of the cost function and the explicit role of volatility. We discuss the implications for price dynamics and the impact of volatility.

Pindyck (2004) assumes that the marginal convenience yield increases with volatility. The net marginal convenience yield (denoted as ψ_t^n) is defined as the marginal convenience yield net of marginal storage costs. If $\psi_t^n = 0$ and firms expect the price to increase, the net marginal convenience yield is required to drop. For example, firms will increase inventory which implies a shift from current sales to future sales.[1] Unlike volatility, asymmetry is not discussed explicitly in Pindyck (2004). Here we will focus on the dynamics implied by the model.

Pindyck (2004) shows that there is a trade-off between selling out of inventory versus production. The optimal response to a cost shock requires that the expected difference in the price equals both the cost of selling out of inventory and the marginal cost of production. In response to cost shocks there are two possibilities: either production adjusts to the shock or the cost shock is absorbed by inventory changes. If there are no adjustment costs of production prices are adjusted instantaneously and production absorbs all cost shocks. Now the firm chooses the level of inventory that satisfies the condition that the net marginal convenience equals zero. Another possibility is that the net marginal convenience yield equals zero for all levels of inventory. In that case all cost shocks are absorbed by inventory changes and production never alters. This illustrates the trade-off implied by the first-order conditions if prices adjust instantaneously or have adjusted in the long run. As a consequence lagged price adjustment in the short run requires sticky production and net marginal convenience yield that decreases if the level of inventory increases.[2] Whether or not the trade-off implies asymmetric responses to cost shocks, either in the short-run or in the long-run, is settled by the empirical results. We will focus on asymmetry in the trade-off between production and selling out of inventories after cost shocks.

[1] It is assumed that the firm is a pricetaker. To introduce market power we can rewrite the problem as a monopoly problem by making the price a function of sales. The result is similar except that the marginal revenue equals total marginal economic cost and the expected difference in marginal revenues equals the cost of selling out of inventory (see Borenstein and Shepard, 2002, p. 138).

[2] In weekly data, we find a negative, but rather weak, negative correlation.