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Anticipated and unanticipated effects of crude oil prices and gasoline inventory changes on gasoline prices ☆

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ABSTRACT

This paper examines the effect of anticipated and unanticipated changes in oil prices and gasoline inventory on US gasoline prices. We estimate empirical responses to anticipated and unanticipated changes in oil prices and gasoline inventory and show that gasoline price adjustments are faster and stronger for anticipated changes in oil prices and inventory levels than for unanticipated changes. Furthermore, this difference is statistically significant. We use these findings to evaluate the cost of adjustment hypothesis suggested by Borenstein and Shephard (2002). We also find that there is an asymmetry in the effect of gasoline inventory on gasoline and oil prices. This finding complements a well-known result that positive and negative changes in oil prices have asymmetric effect on gasoline prices.

1. Introduction

The question of lags in the response of gasoline prices to oil price changes has received considerable attention from researchers. Since the study by Borenstein et al. (1997) which illustrates that gasoline prices adjust slowly to changes in crude oil prices, several explanations of the observed phenomena have been suggested and tested. Borenstein and Shepard (2002) argue that the slow response of gasoline prices is attributed to the high cost of adjustment of production and inventory.[2] Johnson (2002) argues that a search cost may lead to long lags in the response of gasoline prices. Godby et al. (2000) empirically explore the behavior of gasoline and oil prices and suggest that only oil price changes that are bigger than some threshold level leads to revision of gasoline prices. Similar results were obtained by Radchenko (2005a) who points to possible nonlinearities in retail gasoline prices and the role that different kinds of oil price fluctuations play in the gasoline price response.

In this paper, we add new evidence to the literature by examining the response of gasoline prices and inventories to anticipated and unanticipated oil price shocks. We use a methodology originally developed by Cochrane (1998) to distinguish between the effects of anticipated and unanticipated shocks and apply it to analyze the lags in the response of gasoline prices and inventories. The analysis is conducted in two steps. First, we develop a reduced form model[3] that captures interactions between oil prices, gasoline prices and gasoline inventories. Second, applying the Cochrane methodology to our model we estimate and compare effects of anticipated and unanticipated shocks.

The findings of our paper can be summarized as follows. First of all, we show that anticipated shocks lead to significantly stronger and faster response than unanticipated shocks. The latter is consistent with the cost of adjustment hypothesis proposed by Borenstein and Shepard (2002). The reason is that the production and holding costs can make it sub-optimal for refineries to adjust immediately. When the shock is anticipated, refineries have an option of beginning the adjustment earlier, in particular, prior to the shock. With the unanticipated shock, refineries do not have such an option which makes the unanticipated response more delayed. As for the fact that the response to an anticipated shock is stronger, we argue in the paper that it is hard to reconcile with the solely cost-related reasons. We conjecture that incomplete information about the shock and subsequential learning might be partially responsible for a stronger response to an anticipated shock.

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[2] Consideration of the inventory adjustment cost along with the production adjustment cost is important because it is known that many commodities do not exhibit statistically significant cost of adjusting production. See Pindyck (1994) who presents evidence of insignificant cost of adjustment for copper, heating oil, and lumber.

[3] Even though we use a reduced form approach, we show in the paper that the estimated effects of the shocks, in particular their signs, are consistent with structural theoretical models considered in the literature.

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Our second finding is that we observe a statistically significant asymmetry in the effects of positive and negative oil and inventory shocks. In the literature, it has been already established that positive oil shocks have stronger effect on gasoline prices than negative shocks.[4] We replicate this finding in our analysis and in addition we demonstrate that the inventory shocks also have this asymmetric effect on gasoline prices. The positive inventory shocks, which we interpret as demand shock, produce more pronounced response that is significant both in the short- and the long-run. The negative inventory shocks have much weaker effect that is significant only in the short-run.

Third, we show that gasoline inventory level has a "feedback" effect on oil prices. This finding is new in the literature and perhaps somewhat surprising because oil prices could be considered exogenous for gasoline industry. However, both anecdotal evidence and the common sense suggest that this effect might exist.[5] We show in the paper that inventory shocks do have a significant effect on oil prices and it is also asymmetric. An increase in the inventory level leads to a significant decrease in oil prices, whereas a decrease in inventories does not have a significant effect.

The contribution of our paper to the literature is three-fold. First, using Cochrane methodology we develop and estimate an adjustment model that allows anticipated and unanticipated shocks to have different effects on gasoline prices and other variables of interest. This is particularly important since accounting for such a difference can explain the difference in results reported in the literature. Furthermore, allowing anticipated and unanticipated shocks to have different effects provides additional evidence to evaluate the Borenstein and Shepard (2002) result. Second, we include the gasoline inventory variable into our analysis. The inclusion of inventories is a very natural step given that inventory level is one of the main decision variables for producers together with output prices and production levels. However, to our knowledge this is the first paper that uses inventory data in the analysis of delayed adjustment of gasoline prices. Finally, the inclusion of inventory variable into the analysis enables us to investigate questions that were not previously addressed in the literature. In particular, we show that there is an asymmetry in gasoline and oil price responses to inventory shocks and that there is a "feedback" effect of gasoline inventories on oil prices.

The structure of the paper is as follows. We present motivation for considering the model that separates anticipated and unanticipated shocks in Section 2. In Section 3, we explain the details of the econometric approach that we use to construct gasoline price responses to anticipated and unanticipated movements in oil prices and gasoline inventory. In Section 4, we describe the data and results. Concluding remarks are in Section 5.

2. Theoretical background and motivation

This section consists of two parts. In the first part, we motivate the importance of separating the effects of anticipated and unanticipated shocks. In the second part, we review dynamic pricing models which will be useful for interpreting our results.

2.1. Motivation for separating the effects of anticipated and unanticipated shocks

One reason to separate the impacts of anticipated and unanticipated oil price shocks is that such a separation can help to interpret empirical evidence on the source of lags in the response of gasoline prices. There are many papers, including that of Radchenko (2005a), that empirically explore the relationship between oil and gasoline prices. Their common aspect is that the authors compute the measures of gasoline price adjustments to the changes in oil prices without explaining whether these adjustments are in response to *anticipated*, or *unanticipated* oil price changes, or perhaps both. This leads to differences in the reported results from various empirical models, most notably, from the error correction models (ECM) and the vector autoregressive model (VAR).

As we will demonstrate the difference is due to the effect that the measures of the gasoline price adjustment from the VAR and ECM gasoline models describe different phenomena. The measure of the adjustment of gasoline prices from a VAR model captures the response of gasoline prices only to *unanticipated* oil price changes.[6] The measure of gasoline price adjustment from an ECM type model captures the response of gasoline prices to a combination of *both* anticipated and unanticipated oil price changes by *implicitly* assuming that both types of price changes have the same effect on gasoline prices.

Both models are unrealistic. It is unlikely that anticipated and unanticipated oil price changes have the same effect on the gasoline price, as in ECM, or that only unanticipated oil price changes influence the gasoline price, as in VAR. We apply a model that allows both kinds of oil price changes to have a different impact on gasoline prices and show how one may recover the measures of gasoline price adjustment to different kinds of oil price movements. In particular, the proposed model nests the ECM and VAR models as special cases and allows us to test whether anticipated and unanticipated shocks have the same effect and whether it is possible that only unanticipated shocks have effect on gasoline prices.

Another reason for the separate analysis of effects of anticipated and unanticipated oil price changes is that it provides additional evidence to evaluate the Borenstein and Shepard (2002) result. In that paper, the authors argued that it is the costly adjustment of production and inventories that leads to lagged response of gasoline prices. Using our data we can examine this hypothesis based on the timing and the strength of the response. In terms of timing, the hypothesis will be supported by empirical evidence if the response to unanticipated changes in oil prices is more lagged than the response to anticipated changes. This is one of the findings presented in this paper.

To evaluate the costly adjustment hypothesis in terms of the strength of the response, we need to keep in mind that different assumptions on the timing and cost structure, can produce different outcomes. In particular, depending on whether the cost structure is convex or not refineries will adjust either with many small or few big changes. Consequently, we could expect that the response to the anticipated shock should be smaller and shorter if the cost is convex, since firms will start adjustment prior to anticipated shocks. Alternatively, if the cost is non-convex there might be less of a difference in responses to anticipated and unanticipated shocks. We argue in the paper that empirical evidence on the strength of the response while do not contradict the adjustment cost hypothesis

[4] One may refer to the results and references in papers by Borenstein et al. (1997), Galeotti et al. (2003), Balke et al. (2002) or Bacon (1991).

[5] For example, after the weekly inventory report by the Energy Information Administration on January 10 of 2007, crude oil price fell by 3% during one day because gasoline and distillate inventory *increased* by 1.8% and 3.8% respectively. A decline in crude oil price occurred despite a 1.5% *decrease* in the crude oil inventory level. As some traders put it: "It really has not been a crude inventory problem... It has been a refined product problem." For more details one may check http://money.cnn.com/2007/01/10/markets/oil_eia/index.htm?postversion=2007011011.

[6] Christiano et al. (1998) point out that the VAR methodology is asymptotically equivalent to the following two step procedure. In the first step, realized shocks are estimated by the fitted residuals in the ordinary least squares regression of the variable of interest on the variables in the information set. In the second step, a researcher estimates the dynamic response of a variable to shocks by regressing the variable on the current and lagged values of the estimated shocks (residuals).