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Regarding: Proposal for NBER Project on the Economics of Energy Markets

Project title: Crude Oil, Gasoline, Ethanol and Corn: Four Markets, Three Markets, Two Markets or One?

Gasoline in the United States since mid-2006 has been produced by refining crude oil and blending the resulting low-grade gasoline with ethanol, which in turn is being produced from corn. At present, about 10% of U.S. gasoline sold at the pump is made up of ethanol. The ethanol content of gasoline is not an economic choice, but is set by law. This fact makes the ethanol and corn industry an integral part of the U.S. energy infrastructure.

Although there have been many analyses of the crude oil, gasoline, ethanol and corn markets in isolation (and of the oil and gasoline markets and the ethanol and corn markets, respectively, two at a time), only recently attention has been given to the close economic relationship between all four markets (see, e.g., Carter, Rausser and Smith 2013; Baumeister and Kilian 2014a).

We are interested in particular in understanding the nature of the price expectations in these few markets and of the price of risk. A key objective is to understand the expectations that have prevailed in each of these markets since 2005, differentiated by horizon, and how these expectations have responded to legislative changes in biofuel policies. Given the complexity of the relationship between these four markets, the fact that this relationship is rapidly evolving, and the fact that we only have a few years of data, conventional econometric approaches to estimating price expectations in these markets are of limited use. Nor are there reliable survey data of price expectations from market participants. Thus, currently nothing is known about these price expectations and about how their relationship has evolved over time.

Our analysis of this question builds on recent methodological advances in measuring the market expectation of the price of crude oil based on information from futures markets. Baumeister and Kilian (2014b) show that this expectation may be inferred from the prices of oil futures contracts with the help of recently proposed term structure models (see Hamilton and Wu 2014). Although oil futures prices themselves tend to be poor measures of expectations, especially at short horizons, economically plausible and quite accurate measures of price expectations may be obtained by adjusting the oil futures price by the estimated risk premium. We plan to apply the same strategy to futures prices for crude oil, gasoline, ethanol and corn in an effort to characterize the risk premia and price expectations in these markets. The extent to which risk-premium adjusted futures prices improve the accuracy of price expectations in each market can be formally measured and tested using standard tools from the forecasting literature, as illustrated in Baumeister and Kilian (2014b). To the extent that the WTI and Brent prices of crude oil have

deviated systematically in recent years due to infrastructure constraints, as discussed in Kilian (2015), we will consider both Brent and WTI prices in our analysis.

The plan is to fit the term structure model of Hamilton and Wu (suitably adapted to account for differences in the timing of the contracts across markets) to daily futures prices for crude oil, gasoline, ethanol and corn, measured at the end of each week. Answering the questions of interest in this project will require data starting in 2005 (or slightly earlier) to allow us to capture the effect of the first major legislative change in 2005 on price expectations. More generally, we will develop a time line of subsequent legislative changes to allow a comprehensive analysis of the effects of biofuel legislation on price expectations and the degree of integration across oil, gasoline, ethanol and corn markets. The choice of this starting date also avoids any potential econometric issues regarding a possible structural break in 2004/05 associated with the increased financialization of commodity futures markets (see, e.g., Fattouh et al. 2013; Hamilton and Wu 2014).

An important advantage of our approach compared with alternative model-based estimates of price expectations is that we do not have to take a stand on the nature of the potentially nonlinear relationship between these markets and nonlinearities in the determination of market prices (see, e.g., Serra et al. 2011; Baumeister and Kilian 2014a; Abbott 2014; Wright 2014). The precise nature of this nonlinear relationship is unknown and in any case so complicated as to render other regression-based approaches to estimating the time-varying risk premium infeasible.

Instead, in our approach, the risk premium for each market is defined as the difference between the fitted values of the rational-expectations term structure model, suitably extrapolated to monthly horizons h, and the observed futures price (see Hamilton and Wu 2014). This fact allows us to estimate the risk premium for each market one at a time, with the understanding that whatever role nonlinearities as well as interdependencies across markets play in determining price expectations is incorporated in financial market expectations by construction. After converting the estimated risk premium to U.S. dollars, subtracting this risk premium for horizon h from the futures price of maturity h yields a time series of the h-month ahead price expectation for each of these commodity markets (and a corresponding time series of risk premia). These price expectations matter because they determine decisions about future production and consumption. They affect, for example, investments in corn production, in refineries, and in ethanol plants. They also help us quantify the effects of infrastructure constraints on price expectations.

Our analysis will allow us to address several questions that previously were unanswerable.

● One important question is what effect infrastructure constraints have on price expectations in oil markets and ultimately in related markets such as gasoline, ethanol, and corn. For example, Kilian (2015) already documented that the spread of Brent over WTI spot prices rises with tightening bottlenecks in transporting crude oil by pipeline and by rail, but falls, as new pipelines to refineries in Texas are opened or existing pipelines to the interior of the United States are reversed (or as rail and barge transport capacity to East Coast refiners expands). A natural question to ask then is to what extent the market anticipated the development of new pipeline

infrastructure, in which case one would expect to see a tightening of the spread of Brent over WTI oil price expectations before the opening of new pipelines, and how large the effects of infrastructure bottlenecks on oil price expectations are both in the United States (WTI) and globally (Brent).

It would also be of interest to see how these shifts in oil price expectations affect expectations in ethanol and corn markets, with the demand for corn and ethanol being a function of the effective demand for crude oil. The latter question in turn is complicated by the fact that U.S. gasoline price expectations, owing to the trade channels discussed in Borenstein and Kellogg (2014) and Kilian (2015), are tied to global oil prices (Brent) rather than oil prices in the central United States (WTI), yet demand for ethanol reflects demand for gasoline both from the United States and from abroad, highlighting the importance of viewing these markets jointly.

Similarly, one could interpret a widening spread between corn and ethanol price expectations as evidence of bottlenecks in ethanol production (or, alternatively, as evidence of expectations of poor corn crops). The plan is to think through possible interpretations of this spread in expectations ex ante. It may be possible to narrow down the interpretation with the help of additional extraneous information. The key difference from the analysis of the oil market is that the corn and ethanol markets are both for delivery in the Chicago area rather than being spatially separated as in the case of Brent oil (London) and WTI crude oil (Cushing, OK).

It should be noted that, in principle, one could obtain additional information about the role of infrastructure bottlenecks from price data for spatially separated futures markets for oil, gasoline, corn or ethanol, but such spatially separated futures markets simply do not exist. In fact, for a given commodity, trading takes place either in New York or in Chicago for delivery at a unique location in the United States.

● Another question is about changes in the degree of market integration. For example, if the four markets were independent, one would expect there to be no comovement across these time series. The literature on biofuels suggests that these markets are actually closely related (see, e.g., Serra et al. 2011; Mallory, Irwin and Hayes 2012; Baumeister and Kilian 2014a). We are interested in the nature and degree of their comovement. For example, if these markets were perfectly integrated, one would expect the price expectations to move proportionately and at the same time. This is unlikely, but one would expect the price expectations for oil and gasoline, for example, to move together in the long run. The most interesting question is whether there is similar comovement with respect to ethanol and corn prices, compared to one another and compared to oil and gasoline prices, which would be evidence that indeed some food commodity markets after the introduction of biofuel policies in 2005 have been directly tied to energy markets. It is not only spreads between price expectations that provide useful information about market integration. In addition, the sign of the risk premium (and its evolution over time) offers additional information on whether a given futures market is a buyer's or a seller's market, providing yet another measure of market integration that can be assessed with the help of statistical measures of directional accuracy.

In practice, this analysis will be complicated by the fact that an oil price increase reflecting higher demand for oil driven by a booming economy, for example, has fundamentally different effects on the demand for corn and ethanol than an oil price increase driven by an oil supply disruption (see Baumeister and Kilian 2014a). This fact suggests that one could use patterns in the expectations of all four commodities to classify the data into subperiods corresponding to different economic situations that could not be determined based on any univariate time series alone.

● Yet another important question in the literature has been to what extent biofuel markets anticipated the shift in demand triggered by legislative changes mandating the increased use of ethanol (see, e.g., Carter et al. 2013). To date no one has been able to measure the price expectations in these markets and to document how they have evolved in response to institutional changes. One of our objectives is to provide a comprehensive analysis of how legislative changes affected the level of price expectations in each of the four markets as well as the degree of market integration. A legislative initiative, at the time it is introduced (as opposed to enacted) may, for example, cause an upward shift in expectations or a change in the rate of change in one or more measures of price expectations. Such evidence would allow us, for example, to empirically evaluate the conjecture of Wright (2014) that expectations-induced demand for storage explains much of the increase in corn prices following shifts in biofuel policies in recent years. Without a pronounced change in price expectations that hypothesis would seem implausible.

● Another interesting question is how the oil price decline since June 2014 has affected price expectations in the ethanol and corn markets. To the extent that this price decline is driven in substantial part by oil-market specific determinants, as shown in Baumeister and Kilian (2015), this comparison will provide some identifying information about how tight the link between the four markets of interest is.

● Finally, our estimates of price expectations will allow us to construct empirical estimates of the price shocks (or price surprises) in each one of these four markets. This not only will help us to assess the degree of market integration from yet another perspective based on the correlations across price shocks in different markets, but it may also allow the construction of estimates of the price elasticity of supply in the corn and ethanol markets in response to exogenous shifts in biofuel demand based on distributed lag regressions.

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Conflict of interest:
We have no financial interests related to this project and no ties to the energy industry.