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Jump processes in natural gas markets

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ABSTRACT

Many analysts believe that natural gas will have an increasingly important role in the next few decades. Accordingly, understanding the underpinnings of natural gas prices is likely to be critical, both to policy analysts and to market participants. At present, it is common to assume that these prices follow a geometric Brownian motion, *i.e.*, that log returns – the inter-temporal differences in the natural log of prices – are normally distributed (possibly allowing for some form of mean-reversion). Increasingly, however, it has been recognized that the arrival of new information can lead to unexpectedly rapid changes – or jumps – in spot prices. The implication is that the presumption of normally distributed log-returns may be suspect. In particular, the prospect for abnormally fat tails becomes important. This article investigates the potential presence of jumps in two key natural gas prices: the spot price at the Henry Hub in the U. S., and the spot price for natural gas at the National Balancing Point in the U. K. We found compelling empirical evidence for the importance of jumps in both markets, though jumps appear to be more important in the U. K.

1. Introduction

Over the course of the next several years, a number of important events are likely to impact the market for natural gas. Between the potentially controversial and widespread adoption of hydraulic fracturing on the one hand, and the likely move away from coal to natural gas as an important fuel for electricity generation on the other hand, significant changes are likely to come to the fore. To accommodate these potential increases in natural gas commerce, substantial changes in the underlying infrastructure will likely be needed. Power plants will have to be retrofitted or replaced, and pipeline networks will have to be expanded; both reflect large-scale investments. These investments must be contemplated in a world of profound uncertainty, in particular as regards the price path for natural gas. As such, there is a real premium of developing a better understanding of the fundamental stochastic process driving natural gas prices.

Many analysts have suggested that these prices follow a geometric Brownian motion (GBM), *i.e.*, that log returns – the inter-temporal differences in the natural log of prices – are normally distributed (possibly allowing for some form of mean-reversion).[2] Increasingly, however, it has been recognized that the arrival of new information can lead to unexpectedly rapid changes, also known as "jumps", in spot prices (Askari and Krichene, 2008; Benth et al., 2008; Carmona and Ludvoski, 2010; Chen and Forsyth, 2007; Lee et al., 2010; Postali and Picchetti, 2006; Thompson et al., 2009; Wilmot and Mason, 2013). The implication is that the presumption of normally distributed log-returns may be suspect. In particular, the prospect for abnormally fat tails becomes important.

It is interesting in this regard to draw a contrast to crude oil prices. A host of papers have investigated the time series properties of oil prices, pointing to important structural breaks, time-varying volatility and the potential for abrupt and unexpected changes. Perhaps the attention allocated to oil prices is a reflection of the singular importance of the resource in the modern world economy. But as we noted above, natural gas seems poised to emerge as a similarly important resource. In light of this contrast, it is somewhat surprising that comparatively little work has been done to identify key properties of natural gas prices.

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[2] Early examples of papers that argue for the use of GBM to describe oil or gas prices include Baker et al. (1998); Sadorsky (1999) and Schwartz and Smith (2000). Other authors have suggested expanding this paradigm to allow for mean-reversion; examples include Pindyck (1999) and Abadie and Chamorro (2009). On the other hand, Geman (2005) has suggested that mean reversion may no longer apply, and that GBM satisfactorily represents natural gas prices, should one choose to exclude the possibility of jumps. Similarly, Cuddington and Wang (2006) found that U.S. natural gas prices are not mean reverting.

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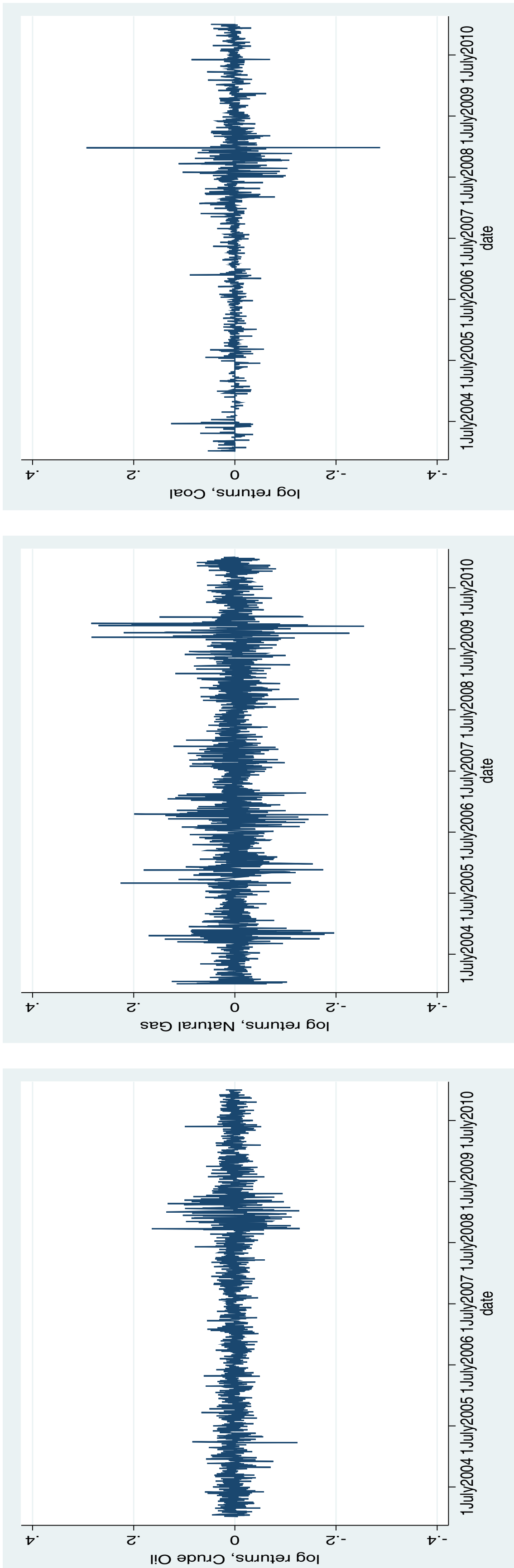

Fig. 1. Log price returns for 3 key energy resources: Crude oil (left panel), natural gas (center panel), coal (right panel).

Table 1
Summary statistics, natural gas price returns.

	NBP	Henry Hub
Sample range		
Start	10 Sept., 2007	07 Jan., 1997
End	30 Sept., 2013	07 Oct., 2013
Summary statistics		
Mean	0.028	−0.0013
Median	0.000	0.000
Min	−25.49	−56.82
Max	24.12	57.67
Std. deviation	4.443	2.370
Variance	21.87	19.74
Coeff. of variation	166.4	−3466
Skewness	−0.066	0.493
Kurtosis	8.790	23.61
DH test statistic[a]	782.0	9363
Number of obs'ns	1542	4193

[a] 1% critical value = 9.21.

This oversight is perhaps all the more puzzling when one considers the relative magnitude of variation in the two price series. In Fig. 1, we plot the log returns for the three major energy resources – oil, natural gas and coal – for the period from January 2004 to January 2010.[3] Two factors jump out from this comparison. First, natural gas prices are considerably more volatile than the other fuels; and second, large sudden changes in the spot price of natural gas are more frequent and larger than for the two other fuels. These observations suggest that the appropriate model of the underlying stochastic process governing natural gas prices is likely to be considerably more complicated than a simple Brownian motion (BM), or geometric Brownian motion (GBM), process. The significance of this point, in turn, is underscored by the attention these two processes have received in the investment under uncertainty literature. Since the large-scale investments one imagines will be undertaken to capitalize on the apparent abundance of natural gas, and its apparent emerging demand, developing a deeper understanding of the stochastic processes driving natural gas prices would seem to have considerable importance, from both a private and a social perspective.

Our goal in this paper is to provide such an understanding. To this end, we first describe an extension of the familiar model of a stochastic process that allows for unexpected changes, or jumps. This extension leads naturally to an econometric specification, which can be readily combined with time-varying volatility (also known as the generalized autoregressive conditional heteroscedasticity, or GARCH, framework). After incorporating these elements, we characterize the likelihood function that governs the data generating process; this, in turn, leads directly to an estimation procedure and hypotheses tests regarding the appropriate specification of the stochastic process.

We then apply this econometric methodology to two important time series for natural gas prices: the spot price of natural gas at the Henry Hub in the U. S. (which is the major U. S. trading hub), and the spot price for natural gas at the National Balancing Point in the U. K. Our data is based on daily observations, for both spot prices. We compare four stochastic data-generating processes: GBM (which we refer to as PD in the pursuant discussion), GBM allowing for a jump diffusion process (which we refer to as JD in the pursuant discussion), GBM allowing for GARCH (which we refer to as GPD in the pursuant discussion), and GBM allowing for both GARCH and a jump diffusion process (which we refer to as GJD in the pursuant discussion). Our findings generally point to the statistical importance of allowing both GARCH and jumps.

[3] All plots reflect daily observations on spot prices. The specific prices used are West Texas Intermediate for oil, Henry Hub for natural gas, and Central Appalachian for coal. Data were taken from the Energy Information Administration website.