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Chaos in oil prices? Evidence from futures markets

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Abstract

We test for the presence of low-dimensional chaotic structure in crude oil, heating oil, and unleaded gasoline futures prices from the early 1980s. Evidence on chaos will have important implications for regulators and short-term trading strategies. While we find strong evidence of non-linear dependencies, the evidence is not consistent with chaos. Our test results indicate that ARCH-type processes, with controls for seasonal variation in prices, generally explain the non-linearities in the data. We also demonstrate that employing seasonally adjusted price series contributes to obtaining robust results via the existing tests for chaotic structure. Maximum likelihood methodologies, that are robust to the non-linear dynamics, lend support for Samuelson's hypothesis on contract-maturity effects in futures price-changes. However, the tests for chaos are not found to be sensitive to the maturity effects in the futures contracts. The results are robust to controls for the oil shocks of 1986 and 1991.

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1. Introduction

It has been well documented that non-linear relationships that are deterministic can yield highly complex time paths that will pass most standard tests of randomness (see Brock, 1986 for a survey). Such random-looking but deterministic series

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have been termed 'chaotic' in the literature (e.g. Devaney, 1986; Guckenheimer and Holmes, 1986). Chaotic dynamics are necessarily non-linear and may be able to explain a richer array of time series behavior. For example, linear models may not properly capture sudden movements and wide fluctuation in stock prices, exchange rates, or in other financial and economic series, while chaotic models may be quite suitable in explaining these behaviors. Furthermore, modeling non-linear processes may be considered less restrictive than linear structural systems as the former are not dependent on the knowledge of the specific underlying structures.

Direct applications of chaos to economic theory has been initiated only in the last 20 years (e.g. Stutzer, 1980; Benhabib and Day, 1981, 1982), with researchers such as Brock and Sayers (1988) employing relatively new techniques to test the null of chaos in a number of macroeconomic series (such as the US unemployment rate).[1] The evidence of chaos in economic time series such as GNP and unemployment has thus far been weak (e.g. Brock and Sayers, 1988).

On the other hand, the few studies on the structure of commodity prices, employing a range of statistical tests, have generally found evidence consistent with low dimension chaos.

Lichtenberg and Ujihara (1988) apply a non-linear cobweb model to US crude oil prices; Frank and Stengos (1989) estimate the correlation dimension and Kolmogorov entropy for gold and silver spot prices; Blank (1991) estimate the Lyapunov exponent for soybean futures; DeCoster et al. (1992) apply correlation dimension to daily sugar, silver, copper and coffee futures prices; Yang and Brorsen (1993) employ correlation dimension and the Brock, Dechert, and Scheinkman (BDS) test on several futures markets.[2]

Why is the evidence of chaos stronger for commodity prices than for economic time series? Baumol and Benhabib (1989) suggest that disaggregated variables (such as commodity prices or production levels), that are inherently subject to resource constraints will make far better candidates for chaotic structure. There may be other reasons for this disparity. Prior studies on the structure of commodity prices suffer from a mixture of short data spans and fairly coarse tests for chaos. Several studies have also failed to control for seasonal variations in commodity prices. To what extent have these factors contributed to the evidence of chaos in commodity prices?

In this paper, we provide evidence on the structure of commodity prices while addressing such questions. We examine the non-linear dynamics and their explanations for three important energy futures contracts: crude oil, heating oil, and unleaded gasoline, from the early 1980s. There is a surprising lack of evidence on

[1] See Baumol and Benhabib (1989) for a more complete review on the application of chaos to economic theory.

[2] Other papers document evidence of non-linearity for various financial and economic time series. For instance, see Hsieh (1989), and Aczel and Josephy (1991) for evidence on exchange rates, Scheinkman and LeBaron (1989), Hsieh (1991) for stock returns, Mayfield and Mizrach (1992) for S & P index prices, and Chwee (1998) for natural gas futures. However, the findings in these papers are not always consistent with chaos. Hsieh (1993) shows that conditional variance effects that are satisfactorily captured by ARCH-type models explain non-linearities in several currency futures contracts.