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Monetary policy regimes in macroeconomic data: An application of fractal analysis

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ABSTRACT

Macromonetary data are examined for behavioral stability over Alan Greenspan's tenure as chairman of the Federal Reserve System. Strong evidence of stochastic dependence is found using Lo's modified rescaled range tests, though not consistently over the earlier, as opposed to the later, subsample. This finding is suggestive of a change in fundamentals such as monetary policy. Then, five self-affine fractal analysis techniques for estimating the Hurst exponent, Mandelbrot-Lévy characteristic exponent, and fractal dimension are employed to explore the data's fractal properties. Techniques are rescaled-range, power-spectral density, roughness-length, variogram, and wavelet analysis. Formal hypothesis tests provide further evidence of a change in monetary policy between the 1989–1996 and 1997–2006 subperiods. This change is manifested both in the behavior and distribution of month-to-month changes in monetary aggregates, ratios, and multipliers, and in the behavior and distribution of macroeconomic data. Most series become significantly less antipersistent after the breakpoint than before. Strong evidence is presented that U.S. monetary policy became actively interventionist after December 1996, and that the effectiveness of the Federal Reserve System has been lowered compared to the earlier period.

1. Introduction

This paper examines the distribution of changes in macromonetary data. Statistical tests for stochastic dependence (Lo, 1991) are supplemented with five alternative methods for estimating Hurst (1951) exponent H, fractal dimension D, and Mandelbrot-Lévy characteristic exponent α (Lévy, 1925). Findings reveal a sharp change in U.S. monetary policy starting in December 1996, announced by Federal Reserve Board Chairman Alan Greenspan's now famous "irrational exuberance" speech (Greenspan, 1996; see also Schiller, 2000).

Mandelbrot's (1972, 1975, 1977) and Mandelbrot and Wallis's (1969d) R/S or rescaled range analysis characterizes time series as one of four types: (1) persistent, trend-reinforcing, or serially correlated series, including biased random walks, random walks with drift, and fractional Brownian motion ($H > 1/2$), (2) true random walks ($H = 1/2$), (3) antipersistent series ($H < 1/2$), or Cauchy processes ($H = 1$). Mandelbrot-Lévy distributions are a general class of infinite-variance probability distributions derived from the generalized central limit theorem, and include the normal or Gaussian and Cauchy as limiting cases (Gnedenko & Kolmogorov, 1954; Lévy, 1925). The reciprocal of the Mandelbrot-Lévy characteristic exponent α is the Hurst exponent H, and estimates of H indicate the probability distribution of a time series. H is also related to the fractal dimension D by the relationship $D = 2 - H$. Series with different fractal statistics exhibit different properties as described in Table 1. Fractal analysis applies only to stationary time series, so non-stationary series must be differenced or rendered stationary by some other means.

Fractal analysis has not typically been used to analyze monetary policy or macroeconomic performance. This methodology provides additional information not offered by more conventional studies and can be used to complement, complete, and more fully interpret earlier studies. This paper's findings are that virtually all macroeonomic series are strongly antiperisistent over the whole

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Table 1
Fractal taxonomy of time series.

Term	Spectrum	Hurst exponent	Fractal dimension	Characteristic exponent
Antipersistent, negative serial correlation, $1/f$ noise, flicker noise	Pink noise	$0 \le H < 1/2$	$1.50 < D \le 2.00$	$2.00 \le \alpha < \infty$
Gaussian process, normal distribution	White noise	$H \equiv 1/2$	$D \equiv 1.50$	$\alpha \equiv 2.00$
Brownian motion, random walk, Wiener process	Brown noise	$H \equiv 1/2$	$D \equiv 1.50$	$\alpha \equiv 2.00$
Persistent, trend-reinforcing, random walk with drift, Hurst process	Black noise	$1/2 < H < 1$	$1 < D < 1.50$	$1.00 < \alpha < 2.00$
Cauchy process, Cauchy distribution	Cauchy noise	$H \equiv 1$	$D \equiv 1$	$\alpha \equiv 1$

Note: Brown noise or Brownian motion is the cumulative sum of a normally distributed white-noise process. The changes in, or returns on, a Brownian motion, are white noise. The fractal statistics are the same for Brown and white noise because the brown-noise process should be differenced as part of the estimation process, yielding white noise.

sample range and both subsamples. Virtually all tests indicate a sharp structural break at the end of 1996, and generally, the series are significantly less antipersistent after the break than before. Because this paper applies a radically different methodology from traditional econometric tests of structural change, its results should be viewed as complementary to applications of Chow (1960) tests and its refinements, such as those of Gregory and Hansen (1996a, 1996b) and Bai and Perron (1998) and Bai and Perron (2003). The paper is organized as follows. A literature review is provided in the second section. The data are documented in the third section. Methodology and results are presented in the fourth and fifth sections. Conclusions are provided in the sixth section.

2. Literature review

The search for long memory in economic time series has been a fixture in the literature applying fractal geometry and chaos theory to economics since Mandelbrot (1963b) shifted his attention from income distribution to speculative prices. Fractal analysis has been applied extensively to equities (Ahmed, Koppl, Rosser, & White, 1997; Banerjee & Mulligan, 2010; Barkoulas & Baum, 1996; Barkoulas & Travlos, 1998; Greene & Fielitz, 1977; Koppl & Nardone, 2001; Kraemer & Runde, 1997; Lo, 1991; Mulligan & Lombardo, 2004; Mulligan, 2004; Peters, 1994, 1996), interest rates (Barkoulas & Baum, 1997a, 1997b; Duan & Jacobs, 1996), commodities (Barkoulas, Baum, & Ogutz, 1998), exchange rates (Andersen & Bollerslev, 1997; Barkoulas & Baum, 1997c; Byers & Peel, 1996; Cheung, 1993; Chou & Shih, 1997; Koppl & Broussard, 1999; Koppl & Yeager, 1996; Mulligan, 2000), and derivatives (Barkoulas, Labys, & Onochie, 1997; Corazza, Malliaris, & Nardelli, 1997; Fang, Lai, & Lai, 1994; Mulligan & Banerjee, 2008). Fractal analysis has also been applied to income distribution (Mandelbrot, 1963a). It has rarely been applied to macroeconomic or monetary aggregates, notably by Peters (1994, 1996) and Mulligan (2010), so the application in this paper is relatively novel. Fractal analysis examines the character of variation in stationary time series, which may change over time, including the relative importance of the most extreme outliers, i.e., empirically characterizing the marginal distribution of a series as fat or narrow tailed.

Ball (2001) found that the increased volatility of M1 velocity after 1980 can be explained largely by volatility in the returns on near monies, suggesting that this volatility was due to substitution between M1 assets and interest-bearing near monies. Clearly, growth in M1 velocity became unstable after 1980 (Fig. 1), but continued on a long-term upward trend, consistent with continued financial innovation in clearing transactions more rapidly. Long-term positive trends have been less clear for M2 velocity (Fig. 2), and MZM velocity (Fig. 3) displays a clear negative trend since 1980. Both the volatility in the growth of M1 and M2 velocity, and the downward trend in MZM velocity, seem to result from increased volatility in returns on savings assets (consistent with activist monetary policy), as well as the general decline in real returns (consistent with expansionary policy), since 1980. Greater volatility also accompanied increased reliance on sweep accounts used to maximize returns by holding as much wealth as possible in interest-bearing non-monetary assets, as well as increased reliance on other automatic electronic transfers, and off-balance-sheet transactions used to extract a higher return, as returns

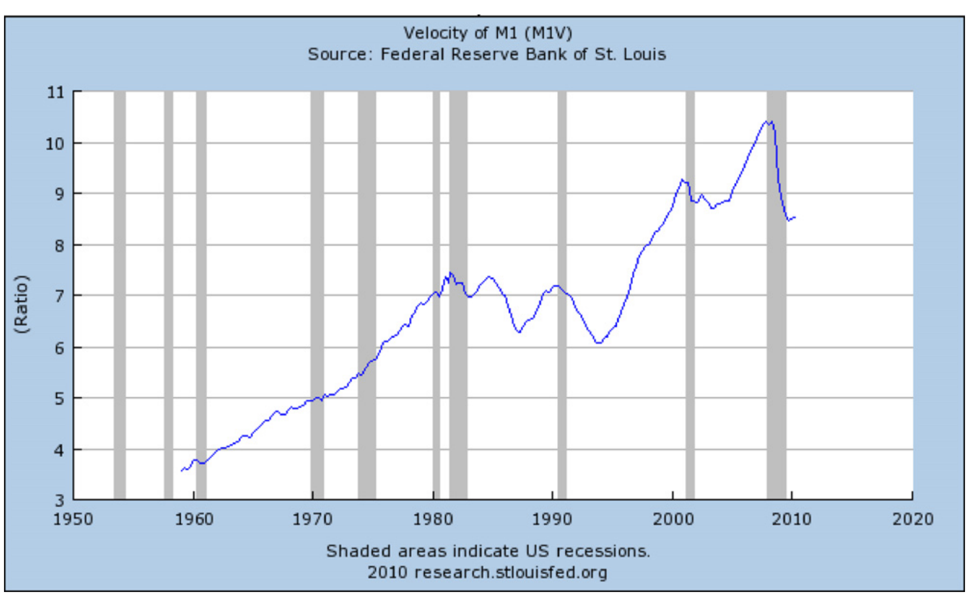

Fig. 1. M1 velocity, 1959–2010.