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An evolutionary game theory explanation of ARCH effects

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Abstract

While ARCH/GARCH equations have been widely used to model financial market data, formal explanations for the sources of conditional volatility are scarce. This paper presents a model with the property that standard econometric tests detect ARCH/GARCH effects similar to those found in asset returns. We use evolutionary game theory to describe how agents endogenously switch among different forecasting strategies. The agents evaluate past forecast errors in the context of an optimizing model of asset pricing given heterogeneous agents. We show that the prospects for divergent expectations depend on the relative variances of fundamental and extraneous variables and on how aggressively agents are pursuing the optimal forecast. Divergent expectations are the driving force leading to the appearance of ARCH/GARCH in the data.
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The goal of volatility analysis must ultimately be to explain the causes of volatility. While time series structure is valuable for forecasting, it does not satisfy

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> our need to explain volatility. ... Thus far, attempts to find the ultimate cause of volatility are not very satisfactory.
>
> Robert Engle (2001)
>
> Few models are capable of generating the type of ARCH one sees in the data. ... Most of these studies are best summarized with the adage that "to get GARCH you need to begin with GARCH."
>
> Adrian Pagan (1996)

1. Introduction

ARCH/GARCH models have been used to describe the behavior of inflation, interest rates and exchange rates,[1] and they have become the standard tool for analyzing returns in financial markets.[2] Despite the widespread empirical successes of ARCH/GARCH models, discovering underlying mechanisms that lead to time-varying volatility has proved to be an elusive goal.

We propose that time-varying volatility is a natural feature of models with forward-looking agents. Our key condition is that agents are not constrained by assumption to agree on a single expectation. Instead, we apply recent developments in evolutionary game theory to explain how forward-looking agents might choose among differing forecasts. We assume that information arrives uniformly over time so that changes in volatility are due entirely to agents' behavior. Furthermore, our agents do not set out simply to invent ARCH. They use ideas drawn from the literature on rational expectations to choose among forecasts based on what they perceive to be fundamentals. We establish conditions under which ARCH effects will be a normal feature of the resulting data.

The mechanism generating time-varying volatility has a general formulation. Evolutionary game theory describes how fractions $x_t = (x_{1,t}, \ldots, x_{k,t})$ of the population using forecasting strategies $s_t = (s_{1,t}, \ldots, s_{k,t})$ evolve according to the performances of the strategies. An asset pricing model then shows how the price y_t depends on the fractions x_t and other information Θ_t so that $y_t = y(x_t, \Theta_t)$. The fractions x_t are taken to be known and fixed before y_t is realized. We divide Θ_t into information Ω_t available to agents before y_t is realized and all other information ε_t. The model generating y_t can then be written in the form

$$y_t = y(x_t, \Omega_t, \varepsilon_t). \tag{1}$$

After agents observe y_t, they choose strategies for period $t+1$, updating x_t using a procedure of the form

$$x_{t+1} = g(x_t, y_t, \Omega_t). \tag{2}$$

[1] Bollerslev (1986) examines inflation dynamics with a GARCH model. Engle et al. (1987) use the ARCH in mean model to study yield curve issues. Diebold and Nerlove (1989) use a multivariate ARCH model to analyze exchange rates.

[2] Engle (2001) provides a recent account of the methodology.

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