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Change point and trend analyses of annual expectile curves of tropical storms

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ABSTRACT

Motivated by the conjectured existence of trends in the intensity of tropical storms, new inferential methodology to detect a trend in the annual pattern of environmental data is developed. It can be applied to any data which form a time series of functions. Other examples include annual temperature or daily pollution curves at specific locations. Within a framework of a functional regression model, two tests of significance of the slope function are derived. One of the tests relies on a Monte Carlo distribution to compute the critical values, the other is pivotal with the chi–square limit distribution. Full asymptotic justification of both tests is provided. Their finite sample properties are investigated by a simulation study. Applied to tropical storm data, these tests show that there is a significant trend in the shape of the annual pattern of upper wind speed levels of hurricanes.

1. Introduction

A great deal of research in environmental and climate sciences has been dedicated to detecting change points and trends in various time series, including those related to temperature, precipitation and wind speed. In a typical setting, a scalar time series $X_1, X_2, \ldots, X_N$ is analyzed. Sometimes several correlated series are considered. Most environmental and climate series exhibit a pronounced annual periodicity which must be removed, or otherwise accounted for, before statements on change–points or trends can be inferred. Sometimes, it is difficult to approximate the periodic component by a Fourier expansion due to the irregular domain and amplitude of observations within a year. The data that motivate this work are tropical storm wind speed data, examples are shown in Figs. 1 and 2. By definition, only storms having the wind speed over 63 kilometers per hour are considered as tropical storms. The onset and end of typhoon and hurricane seasons, as well as their intensity, can change from year to year. We therefore propose to treat the data available for a whole year as a single high–dimensional data object and perform the change point and trend analyses on these objects rather than the scalar observations directly. Such an approach is now relatively well–established in the field of functional data analysis (FDA), the monographs of Horváth and Kokoszka (2012) or Ferraty and Vieu (2006) contain many examples. Methodological foundations of FDA are addressed in Ramsay and Silverman (2005), its mathematical foundations in Hsing and Eubank (2015). While the amount of information available in the data is invariably reduced by various smoothing and dimension reduction methods, the most

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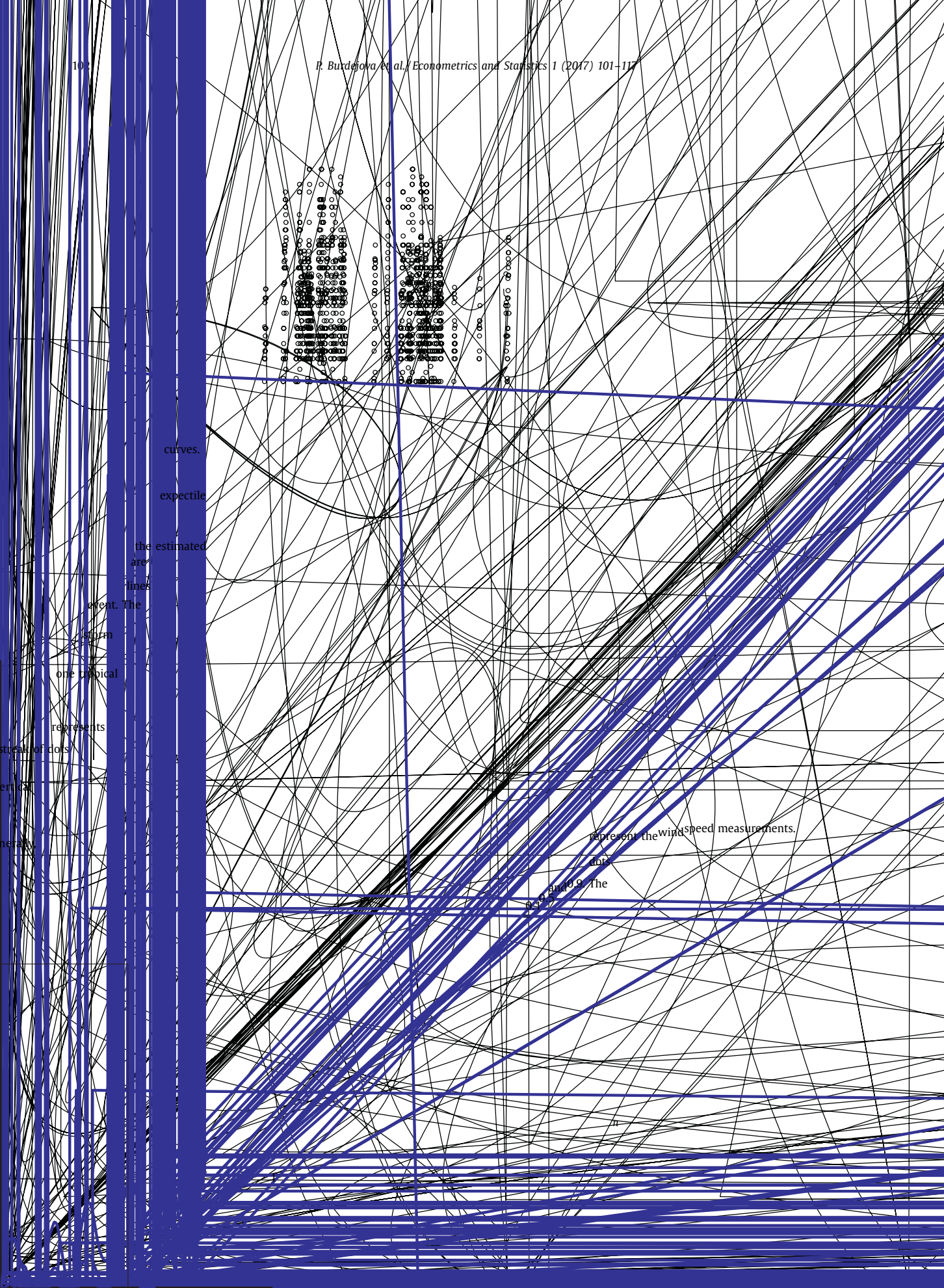

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