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Tests for skewness and kurtosis in the one-way error component model

Antonio F. Galvao [a,*], Gabriel Montes-Rojas [b,c], Walter Sosa-Escudero [d,e], Liang Wang [f]

[a] *Department of Economics, University of Iowa, W284 Pappajohn Business Building, 21 E. Market Street, Iowa City, IA 52242, United States*

[b] *CONICET-Universidad de San Andrés, Argentina*

[c] *Department of Economics, City University London, Northampton Square, London EC1V 0HB, UK*

[d] *Department of Economics, Universidad de San Andrés, Argentina*

[e] *CONICET, Argentina*

[f] *Department of Economics, University of Wisconsin-Milwaukee, NWQ B, 2025 E. Newport Ave., Milwaukee, WI 53201, United States*

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This paper derives tests for skewness and kurtosis for the panel data one-way error component model. The test statistics are based on the between and within transformations of the pooled OLS residuals, and are derived in a moment conditions framework. We establish the limiting distribution of the test statistics for panels with large cross-section and fixed time-series dimension. The tests are implemented in practice using the bootstrap. The proposed methods are able to detect departures away from normality in the form of skewness and kurtosis, and to identify whether these occur at the individual, remainder, or both error components. The finite sample properties of the tests are studied through extensive Monte Carlo simulations, and the results show evidence of good finite sample performance.

1. Introduction

The need to check for non-normal errors in regression models obeys to both methodological and conceptual reasons. From a strictly methodological point of view, lack of Gaussianity sometimes harms the reliability of simple estimation and testing procedures, and calls for either better methods under alternative distributional assumptions, or for robust alternatives whose advantages do not depend on distributional features. Alternatively, whether errors should be more appropriately captured by skewed and/or leptokurtic distributions may be a statistical relevant question *per se*.

The normality assumption also plays a crucial role in the validity of specification tests. Blanchard and Mátyás [9] examine the consequences of non-normal error components for the performance of several tests. In a recent application, Montes-Rojas and Sosa-Escudero [27] show that non-normalities severely affect the performance of the panel heteroskedasticity tests by Holly and Gardiol [21] and Baltagi et al. [5], in line with the results of Evans [15] for the cross-sectional case. Despite

* Corresponding author.
E-mail addresses: antonio-galvao@uiowa.edu (A.F. Galvao), Gabriel.Montes-Rojas.1@city.ac.uk (G. Montes-Rojas), wsosa@udesa.edu.ar (W. Sosa-Escudero), wang42@uwm.edu (L. Wang).

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these concerns the Gaussian framework is widely used for specification tests in the one-way error component model; see, for instance, the tests for spatial models in panel data by Baltagi et al. [7], and Baltagi, Song, Jung, and Koh [6].

Even though there is a large literature on testing for skewness and kurtosis in cross-sectional and time-series data, including Ergun and Jun [13], Bai and Ng [4], Premaratne and Bera [29], Dufour et al. [12], Bera and Premaratne [8], Henze [20] and Lutkepohl and Theilen [25] to cite a few of an extensive list that dates back to the seminal article by Jarque and Bera [22], results for panel data models are scarce. A natural complication is that, unlike their cross-section or time-series counterparts, in simple error-component models lack of Gaussianity may arise in more than one component. Thus, an additional problem to that of detecting departures away from normality is the identification of which component is causing it. Previous works on the subject include Gilbert [18], who exploits cross-moments, and Meintanis [26], who proposes an omnibus-type test for normality in both components jointly based on empirical characteristic functions.

This paper develops tests for skewness (lack of symmetry), kurtosis, and normality for panel data one-way error component models. The tests are constructed based on moment conditions of the within and between transformations of the ordinary least squares (OLS) residuals. These conditions are exploited to develop tests for skewness and kurtosis in the individual-specific and the remainder components, separately and jointly. We show that under the corresponding null hypothesis the limiting distributions of the tests are asymptotically normal. To obtain the asymptotic distributions of the test statistics, we consider the most important case where the number of individuals, N, goes to infinity, but the number of time periods, T, is fixed and might be small. The proposed methods and associated limiting theory are important in practice because, in the panel data case, the standard Bera–Jarque test is not able to disentangle the departures of the individual and remainder components from non-Gaussianity.

The proposed tests are implemented in practice using a bootstrap procedure. Since the tests are asymptotically normal, the bootstrap can be used to compute the corresponding variance–covariance matrices of the statistics of interest and conduct inference. In particular, the tests are implemented using a cross-sectional bootstrap. We formally prove the consistency of the bootstrap method applied to our case of short panels.

A Monte Carlo study is conducted to assess the finite sample performance of the tests in terms of size and power. The Monte Carlo simulations show that the proposed tests and their bootstrap implementation work well for both skewness and kurtosis, even in small samples similar to those used in practice. The results confirm that the test for the individual specific component depends on the cross-section dimension only, and hence it is invariant to the time-series dimension. The proposed tests detect departures away from the null hypothesis of skewness and/or kurtosis in each component, and are robust to the presence of skewness and/or kurtosis in the other component.

Finally, to highlight the usefulness of the proposed tests, we apply the new tests to the Fazzari et al. [16] investment equation model, in which firm investment is regressed on a proxy for investment demand (Tobin's q) and cash flow.

The paper is organized as follows. Section 2 presents the relevant moment conditions that characterize skewness and kurtosis for each error component. Section 3 derives the tests and their asymptotic distributions. Section 4 describes the implementation through bootstrap. Section 5 presents Monte Carlo results. A brief application is given in Section 6. Finally, Section 7 concludes and discusses extensions.

2. Skewness and kurtosis in the one-way error component model

2.1. The model and the hypotheses

Consider the following standard panel data one-way error component model

$$y_{it} = \alpha_0 + \boldsymbol{x}_{it}^\top \boldsymbol{\beta}_0 + u_{it}, \quad u_{it} = \mu_i + \nu_{it},\ i = 1, \dots, N,\ t = 1, \dots, T, \tag{1}$$

where α_0 is a constant, $\boldsymbol{\beta}_0$ is a p-vector of parameters, and μ_i, ν_{it}, and $\boldsymbol{x}_{it}$ are copies of random variables μ, ν, and $\boldsymbol{x}$, respectively. As usual, the subscript i refers to individual and t to time. Here μ_i and ν_{it} refer to the individual-specific and to the remainder error component, respectively, both of which have mean zero.

The quantities of interest are each component skewness,

$$s_\mu = \frac{\mu_3}{\sigma_\mu^3} = \frac{\mathrm{E}[\mu^3]}{(\mathrm{E}[\mu^2])^{3/2}}, \quad \text{and} \quad s_\nu = \frac{\nu_3}{\sigma_\nu^3} = \frac{\mathrm{E}[\nu^3]}{(\mathrm{E}[\nu^2])^{3/2}},$$

and kurtosis,

$$k_\mu = \frac{\mu_4}{\sigma_\mu^4} = \frac{\mathrm{E}[\mu^4]}{(\mathrm{E}[\mu^2])^{2}}, \quad \text{and} \quad k_\nu = \frac{\nu_4}{\sigma_\nu^4} = \frac{\mathrm{E}[\nu^4]}{(\mathrm{E}[\nu^2])^{2}}.$$

We are interested in testing for skewness and kurtosis in the individual-specific and the remainder components, separately and jointly. When the underlying distribution is normal, the null hypotheses of interest become $H_0^{s_\mu} : s_\mu = 0$ and $H_0^{s_\nu} : s_\nu = 0$ for skewness, and $H_0^{k_\mu} : k_\mu = 3$ and $H_0^{k_\nu} : k_\nu = 3$ for kurtosis. We also consider testing for skewness and kurtosis jointly. Under normality, the null hypotheses for these cases are given by

$$H_0^{s_\mu \& k_\mu} : s_\mu = 0 \quad \text{and} \quad k_\mu = 3,$$
$$H_0^{s_\nu \& k_\nu} : s_\nu = 0 \quad \text{and} \quad k_\nu = 3.$$