

# Kuznets Curve for the US: A Reconsideration Using Cosummability

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## Abstract

The relationship between income inequality and long-run economic growth has gained a growing attention in economic research for over decades. This study employed advanced time series techniques to examine the existence of an inverted U-shaped long-run relationship between income inequality and economic growth, using long-span time series data for the United States between the periods 1917–2012. The concepts of summability, balancedness and co-summability was advanced to analyze nonlinear long-run relations among stochastic processes. The empirical results find no evidence in support of nonlinear long-run (inverted U-shaped) relationship for the US, but findings from a vocal set of economists lends strong support and is the basis for the conclusions drawn by this study.

## Keywords:

Income inequality, Economic growth, Summability, Balancedness, Co-summability

## Introduction

A study conducted by Kuznets (1955) is continuously referenced by most of the research evaluating the possible relationship between economic growth and income inequality and/or vice versa. Simon Kuznets carried out the study on three great industrialized economies of United States, Germany and United Kingdom. The empirical findings were based on the hypothesis that income inequality rose at the wake of industrialization process and later declined as development processes increased (inverted U-curve). Interestingly, Kuznets neither gave sufficient empirical evidence for testing this assumption for a long temporal change in income inequality, nor could the stages be explicitly dated. Anand and Kanbur (1993)<sup>1</sup> in their analysis, provided a valid explanation for this swing in income inequality for developing countries. Hence, it becomes expedient to consistently take a closer look at Kuznets' study while taking caution when analyzing the relationship between income inequality and economic growth.

The relation between income inequality and economic growth has long been a subject of discussion among economists. Tracing this back to the 1960s, President John F. Kennedy once qualified the relationship between inequality and growth as a rising tide that lifts all boats to illustrate the idea that economic growth is beneficial to both the poor and rich in

the society. In spite of this, whether the poor can access the gains of growth equally as the rich poses debatable questions. The conflicting experience in the aftermath of the Second World War between the East Asia and Latin America cannot be over-emphasized. During this period, Latin America experienced high level of income inequality and moderate growth, while the reverse was the case with East Asia where there was a moderate level of income inequality and glowing economic growth.<sup>2</sup>

The positive relationship between income inequality and economic growth is illustrated as follows. It is expected that in developed economies, the saving habit of the few rich (privileged) should be higher than that of the poor masses (less privileged). Thus, income redistribution from the few rich to poor masses would automatically lower the aggregate saving rate or habit of the entire economy and by implication cause a decrease in economic growth. On the other hand, income redistribution could possibly decrease incentive for the few rich to work hard, which could also cause a decrease in the level of economic growth. On this premise, it is hypothesized that income inequality at a particular time can negatively influence economic growth and other times positively influence economic growth.

In addition, the inverse relationship that has been widely assumed to exist between economic growth and income inequality can be likened to the following illustration. In most developing countries, the less privileged are not considered credit worthy, and so they do not have access to capital. Thus, this scenario incapacitates investment opportunities for the poor, while those who are extremely poor can hardly actively participate in production, thereby resulting to what is obviously an inequality gap. Hence, a decline in the level of economic growth is occasioned by income inequality which leads to social-economic and political instability. To augment this claim, Tuominen (2016a) while reassessing the relationship between economic growth and top-end inequality for 25 countries (developing and developed countries) between the periods 1920–2000, exploits the top 1% income distribution and addresses issues regarding nonlinearity, found that, there exists a significant negative relationship between the top 1% income distribution and economic growth, especially in developed economies, with this relationship becoming weaker as the quest for economic development rises; though, there is a tendency for a positive relationship between the observed variables at the subsequent phases of development (Tuominen 2015). Thus, it is hypothesized that income inequality at a particular time can negatively influence economic growth and at other times positively influence economic growth.<sup>3</sup>

In examining the existence of the Kuznets' inverted-U shape relationship, most of the previous studies follow the parametric quadratic specification by regressing only Gini coefficients as a measure of income inequality on real GDP per capita and its squared term (see Ahluwalia 1976; Hsing and Smyth 1994; Jacobsen and Giles 1998). Empirical findings of a positive and significant estimated coefficient on the real GDP per capita and a negative coefficient on its squared term are perceived as an evidence for the Kuznets' inverted-U shape proposition. However, this econometric method may be subject to model misspecification, so that their empirical results and conclusions may be misleading. A more suitable and simple approach is to allow the data to speak for themselves by using a more flexible and reliable time series methodology such as cointegration, instead of imposing a particular statistical functional form.

Our current study revisits the Kuznets' inverted U-shaped hypothesis for United States. Primarily, the focus of this study is to investigate whether there exists nonlinearity (inverted U-shaped hypothesis) long-run relationship between economic growth and income inequality in the case of United States or not. This study intends to contribute to the growth-inequality literature in three ways. First, this study unlike the others, employed a long and relatively more recent dataset on income inequality and economic growth for the period from 1917 to 2012 using 96 observations. For a study like this, long-span data is required and sufficient for evaluating the inverted U-shaped relationship as it incorporates the transition processes in the economy of United States from certain stages of economic growth to its recent economic status. Second, unlike previous studies that use Gini coefficient only to proxy for income inequality, in our current study we employ six (6) measures of income distribution such as Gini coefficient, Theil, Atkinson, Rmeandev, Top 10 and Top 1% to proxy and as measure of income inequality. This is considered more suitable to capture the inherent existing relationships between economic growth and income inequality, at different levels of income distribution/inequality. Third, to examine the quadratic (nonlinear) econometric techniques of Hsing and Smyth (1994), Jacobsen and Giles (1998), and other existing findings, this study evaluate Kuznets inverted U-shaped relationship using the idea of co-summability. The econometric framework behind cosummability is explained below. To examine linear relationships among continuous economic non-stationary time series data, the cointegration techniques is no doubt a perfect framework. However, the intrinsic linearity in the framework of integration and co-integration makes it inappropriate to evaluate nonlinear long-run relations among non-stationary processes, which is the case when evaluating Kuznets inverted U-curve.

In order to achieve our study objective, we employ the concept of cosummability proposed by Berenguer-Rico and Gonzalo (2013) and the order of summability introduced by Berenguer-Rico and Gonzalo (2014) to deal with nonlinear transformations of time series data. It is assumed that, a cosummable relationship is balanced, when the variables under observation exhibit same order of summability and portray a long-run equilibrium relationship that are nonlinear, provided that the errors have least order of summability. Based on our knowledge, this study appears to the first to use the idea of co-summability proposed by Berenguer-Rico and Gonzalo (2013) to investigate inverted U-shaped relationship between economic growth and income inequality for the United States, using a long-span time series data. The novelty of this study lies in the application of sound, reliable and new time series econometric methods.

The empirical analysis of this study focuses on whether there exists nonlinearity long-run relationship between economic growth and income inequality in the case of United States or not. This study does not consider issues related to direction of causality, which we assume not to have any statistical contribution and validity to our research outcomes. The empirical results of this study provide evidence in support of a long-run linear relationship between income inequality and economic growth for the United States. Our empirical findings provide no evidence in support of the Kuznets' (inverted U-shaped) nonlinear long-run relationship between economic growth and income inequality for the sampled country.

This paper is organized in five other sections. The second section discuss the literature in brief, while third section considers a detail discussion on the concept of summability,

balancedness and cosummability. This is followed by the data and the empirical model used in section four. In section five, the results and empirical findings are discussed, while conclusion is drawn in the last section.

## Literature Review in Brief

Based on existing literature, there are studies conducted primarily on income inequality-economic growth relationship, which have reported extensive conflicting outcomes. These several empirical cross-country surveys chiefly include but is not limited to Alesina and Rodrick (1994), Persson and Tabellini (1994) and other studies (see Wan et al. 2006; Sukiassyan 2007; Majumdar and Partridge 2009; Ogus Binatli 2012; Wahiba and El Weriemmi 2014; Henderson et al. 2015; Tuominen 2015, 2016a, b; Babu et al. 2016) all of which have confirmed the negative relationship. Lately, many research endeavors have found direct (positive) relationship between growth and income inequality (see Li and Zou 1998; Forbes 2000; Partridge 1997; Frank 2009; Muinelo-Gallo and Roca-Sagalés 2013; Chan et al. 2014; Cingano 2014; Fang et al. 2015; Nahum 2005; Rubin and Segal 2015; Saari et al. 2015). While Barro (2000) posits that the relationship between the variables is inconclusive, others found mixed relationship between income inequality and economic growth (see Chen 2003; Voitchovsky 2005; Shin 2012). Notably, the empirical difference in existing datasets, estimation techniques and/or model specifications have been proposed as possible reasons for the differing results from previous studies.

To the best of authors knowledge, there exist only few studies (see Robinson 1976; Braulke 1983; Ram 1991; Fosu 1993; Hsing and Smyth 1994; Nielsen and Alderson 1997; Jacobsen and Giles 1998; Banerjee and Duflo 2000; Chen 2003; Huang 2004; Lin and Weng 2006; Lin 2007; Lin et al. 2007; Kim et al. 2011; Huang et al. 2012; Lessmann 2014; Theyson and Heller 2015), which have specifically investigated the inverted U-shaped relationship between economic growth and income inequality. Using non-parametric estimation techniques in the US for the period from 1947 to 1991, Jacobsen and Giles (1998) could not find evidence in support of Kuznets inverted U-shaped relationship between economic growth and income inequality.

On the other hand, Banerjee and Duflo (2000) revealed through their cross-country analysis that economic growth is an inverted U-shaped function of income inequality. Chen (2003) documented an inverted U-shaped relationship, using Gini coefficient to proxy for income inequality and real gross domestic product (GDP) to proxy for economic growth for a panel countries 54 countries, by employing the Barro-type model over a 22 years period from 1970 to 1992. Huang (2004) employs flexible nonlinear inference method as advanced by Hamilton (2001, 2003) to examine the validity of the Kuznets hypothesis in a cross-country analysis, found an evidence in support of nonlinearity and inverted U-shaped relation between GDP per capita and inequality, thus, confirming the Kuznets hypothesis.

In contrast to the conventional parametric quadratic methods for examining Kuznets hypothesis, Lin and Weng (2006) employ semi-parametric to examine existence of an inverted U-shaped relationship between inequality and GDP per capita in a cross-country analysis and document evidence in support of Kuznets hypothesis, similarly Huang (2004) in a cross-country analysis, found that, Kuznets hypothesis only exist in countries with

moderate income inequality, however, and not in countries with extremely low or extremely high income inequality. Furthermore, Huang and Lin (2007) in their empirical investigation to validate Kuznets hypothesis for 75 countries, using the data obtained from Iradian (2005) unlike the previous studies, found asymmetric relationship between GDP per capita and income inequality. Lessmann (2014) found a strong evidence in support of an inverted U-shaped relationship between spatial inequality and economic development using the same econometric approach for 56 countries for the period from 1980 to 2009, through parametric and semi-parametric regression. Meanwhile, Theyson and Heller (2015) examine the relationship between economic growth/development and income inequality, where Human Development Index (HDI) was used as a proxy for economic development in the context of Kuznets hypothesis for 147 countries between the periods 1997–2007, using time series and panel data analysis. They concluded that using various economic indicators to proxy for development remarkably influence the shape of the Kuznets curve, while increase in the level of income inequality may not be essential part of a nation's developmental process.

Kim et al. (2011) using the pooled mean group (PMG) estimator as advanced by Pesaran et al. (1999) observed a long-run equilibrium relationship between real GDP per capita and inequality for the United States. According to their findings, the relationship between inequality and per capita GDP is U-shaped rather than the conventional inverted U-shaped proposed by Kuznets hypothesis. This resonate with the findings of Huang et al. (2012) on the Kuznets hypothesis for the United States. Patriarca and Vona (2013) examined an inverted U-shaped relationship between structural change and income distribution, and found that in an economy where technology and preference adjust over time, several long-term growth are mostly occur due to various distributive rules controlling the task of innovative rents between entrepreneurs and workers.

## Methodology

In this section, the concepts of summability, balancedness and co-summability as well as the estimation method employed in our empirical analysis are explained as follows.

## Summability

The idea of summability was conceived in Gonzalo and Pitarakis (2006), and recently expounded upon by Berenguer-Rico and Gonzalo (2013, 2014). According to scholars, a random process  $(y_t)$  will be summable of order  $\beta$ , represented as  $S(\beta)$ , if and only if, non-random sequence  $(m_t)$  exist in such a way that,

$$S_T = \frac{1}{T^{1/2+\beta}} L(T) \sum_{t=1}^T (y_t - m_t) = O_P(1) \quad \text{as } T \rightarrow \infty, \quad (1)$$

where  $\beta$  denotes the least real number such that  $S_T$  is stochastically bounded, and  $L(T)$  represents a slowly ranging function.

This concept generalizes the idea of integration in linear form and gives room for establishing order of summability for several nonlinear models. As expected, if a linear  $(y_t)$

time series is  $I(d)$ , thus, it will be summable of order  $d$ , that is,  $S(d)$ . In a situation, where time series  $(y_t)$  is a nonlinear transformation, this demands the use of the concept of summability. In this empirical application, the focus is to evaluate the order of summability of the variables of interest to be incorporated in the polynomial specifications or framework.

### Balancedness

Once the assumption regarding the concept of summability is established, then the balance specification or requirement of the empirical relationship that exist between the variables is then evaluated. That is, evaluating whether both parts of the empirical equation of the model maintain a matching order of summability. The empirical equation specified for the model is given as:  $y_t = f(x_t, \theta)$  where  $y_t$  is assumed to be balanced, if  $y_t \sim S(\beta_y); f(x_t, \theta) \sim S(\beta_f)$

and  $(\beta_y = \beta_f)$  Therefore, we specified the null and alternative hypotheses of balancedness as:

$$H_0: \beta_y - \beta_f = 0$$

$$H_1: \beta_y - \beta_f \neq 0$$

It is pertinent to observe that, under the null hypothesis of balancedness, the related confidence interval includes zero. Therefore, evaluating the variables for balancedness is crucial for the soundness and credibility of the empirical specification in this study.

### Co-summability

Co-summability is a crucial pre-estimation test that should be conducted, to evaluate the validity of an empirical model specified for use along with the balancedness test. Besides, two summable random processes  $x_t \sim S(\beta_x)$  and  $y_t \sim S(\beta_y)$  are assumed to be co-summable, if and only if there exists  $f(x_t, \theta_f) \sim S(\beta_f)$  in such a way that  $u_t = y_t - f(x_t, \theta_f)$  is  $S(\beta_u)$ , where  $\beta_u = \beta_y - \beta_f$ ,  $\beta$  is greater than zero. Then we say that  $(y_t, x_t) \sim CS(\beta_y, \beta)$ .

However, the parametric function of  $f(\cdot, \theta_f)$  can be substituted with a conventional nonlinear function. While  $\beta$ ,  $\beta_y$  and  $\beta_x$  are unknown in application, Berenguer-Rico and Gonzalo (2014) introduced a consistent and more reliable estimator with slow convergence rate of  $\frac{1}{\ln(T)}$ . Considering that, the strong co-summability will indicate that, the order of summability  $\beta_u$  of  $u_t$  is statistically not different from zero. It is worth noticing that under the null hypothesis, we specified that, the confidence interval contains zero.

### Estimation and Inference

The estimation method that we use to estimate the order of summability goes back to McElroy and Politis (2007) and was also detailed by Berenguer-Rico and Gonzalo (2014). For simplicity, let's assume that  $L(T)$  in Eq. (1) is equal to 1. Then,  $y_t$  is summable of order  $\beta$  if

$$S_T = \frac{1}{T^{\frac{1}{2} + \beta}} \sum_{t=1}^T (y_t - m_t) = O_p(1)$$

In addition, to properly use this estimation method, we assume that  $P(S_T = 0) = 0$  for all  $T = 1, 2, 3, \dots$  and subsequently we obtain (see McElroy and Politis (2007))

$$U_T = \ln S_T^2 = \ln \left( T^{-(1+2\beta)} \left( \sum_{t=1}^T (y_t - m_t) \right)^2 \right) = O_p(1)$$

which can be re-written as

$$Y_k = \alpha \ln k + U_k, \quad k = 1, 2, \dots, T. \quad (2)$$

where  $\alpha = 1 + 2\beta$ ,  $Y_k = \ln \left( \sum_{t=1}^k (y_t - m_t) \right)^2$  and  $U_k = O_p(1)$ .

In our paper, the deterministic component  $m_t$  is assumed to be a constant plus trend  $m_t = m_0 + m_1 t$ . Berenguer-Rico and Gonzalo (2014) show that, for this parametric form, the appropriate  $m^\wedge t$  that satisfies  $(y_t - m^\wedge t) \sim S(\beta)$  is a double partial demeaning

$$\hat{m}_t = \frac{1}{t} \sum_{j=1}^t y_j + \frac{2}{t} \sum_{j=1}^t \left( y_j - \frac{1}{j} \sum_{j=1}^j y_j \right)$$

By estimating the regression (2) using the least squares we obtain

$$\hat{\alpha} = \frac{\sum_{k=1}^T Y_k \ln k}{\sum_{k=1}^T (\ln k)^2}$$

and therefore, the ordinary least squares (OLS) estimator of the order of summability  $\beta$  is given by  $\hat{\beta} = \frac{\hat{\alpha}-1}{2}$ .

With regard to the asymptotic properties of this estimator, the authors have shown that

$$\hat{\alpha} - \alpha = \frac{\sum_{k=1}^T U_k \ln k}{\sum_{k=1}^T (\ln k)^2} = o_p(1)$$

Berenguer-Rico and Gonzalo (2014) show that the OLS estimator of  $\hat{\alpha}$  is log T-consistent. They have shown in their proposition 4 that under the assumption of the stochastic boundedness of  $U_T$ , if  $\frac{1}{T} \sum_{k=1}^T U_k \Rightarrow D_U$  and  $\frac{1}{T} \sum_{k=1}^T |U_k|^p = O_p(1)$ , for some  $1 < p < \infty$  and  $D_U$  a random variable, then  $\ln T (\hat{\alpha} - \alpha) \Rightarrow D_U$ .

As far as we know, there are no results on the asymptotic distribution of  $\hat{\alpha}$  and so critical values cannot be tabulated. In order to overcome this problem, we follow Berenguer-Rico and Gonzalo (2014) by using the subsampling methodology of Politis et al. (1999) to obtain

inferences on the order of summability. Note that  $L(T)$  in Eq. (1) is not necessarily equal to 1. In our case, we assume, as in Berenguer-Rico and Gonzalo (2014), that  $L(T)$  is a constant  $c$  different from zero. As a result, Eq. (2) becomes

$$Y_k = \gamma + \alpha \ln k + U_k, \quad k = 1, 2, \dots, T. \quad (3)$$

with  $\gamma = -2 \ln c$ . To overcome the identification problem of the parameter  $\gamma$ , we subtract the first observation from  $Y_k$ , which gives the following the regression

$$Y_k^* = \alpha \ln k + U_k^*, \quad k = 1, 2, \dots, T. \quad (4)$$

where  $Y_k^* = Y_k - Y_1$  and  $U_k^* = U_k - U_1$

We then obtain the least squares estimator

$$\hat{\alpha}^* = \frac{\sum_{k=1}^T Y_k^* \ln k}{\sum_{k=1}^T (\ln k)^2}$$

Which possesses the same asymptotic properties as  $\hat{\alpha}$  and gives the OLS estimator

$$\hat{\beta}^* = \frac{\hat{\alpha}^* - 1}{2}$$

The subsampling inference method of Politis et al. (1999) is employed here for constructing confidence intervals for the summability order  $\hat{\beta}^*$ . In doing so, the above procedure is applied to  $T-b+1$  subsamples of size  $b = \sqrt{T} + 1$ , where  $\lfloor \cdot \rfloor$  is the integer part function.

### Data and Empirical Model

In this section, the data, sources of data and empirical model considered in this study are discussed. Using the assertion by Berenguer-Rico and Gonzalo (2013), the relationship between economic growth and income inequality in a polynomial form is given as:

$$y_t = \beta_0 + \beta_1 z_t + \beta_2 z_t^2 + \dots + \beta_k z_t^k \quad (5)$$

where  $z_t$  is a measure of economic growth and  $y_t$  measures different levels of income distribution. It is crucial to emphasize the following points associated with Eq. (5) above. First, with regards to the measures chosen for  $z_t$ , the most commonly used measure of economic growth is the real gross domestic product per capita i.e. real GDP per capita. In this study, the real GDP per capita is employed to measure the level of economic growth based on data availability for the period from 1917 to 2012. Although reliable data of the real GDP is available until 2015, the data for income distribution is available up to 2012, which is probably the latest data on income distribution. Secondly, for analyzing the relationship between GDP per capita and income inequality, the order of polynomial previously used in the existing literature has either been quadratic or cubic. For quadratic (see Robinson 1976; Banerjee and Duflo 2000; Chen 2003; Patriarca and Vona 2013) and



cubic (see Lessmann 2014). In our analysis, following the methodology of Berenguer-Rico and Gonzalo (2013), we use polynomials of up to 4th order, i.e.  $k = 4$ . Thirdly,  $y_t$  and  $z_t$  are often used in their level forms (see Banerjee and Duflo 2000; Chen 2003; Rubin and Segal 2015) or at times in natural logarithms forms (see Lessmann 2014), while in other cases, they are compared both in levels and natural logarithmic transformation forms (see Muinelo-Gallo and Roca-Sagalés 2013; Babu et al. 2016). Note that Eq. (5) allows for testing the various forms of the relationship between inequality and GDP per capita; (1)  $\beta_1 > 0$  and  $\beta_i = 0$ , for  $i > 1$ , suggests a monotonically increasing linear relationship, meaning that rising incomes are accompanied by rising levels of inequality; (2)  $\beta_1 < 0$  and  $\beta_i = 0$ , for  $i > 1$ , presents a monotonically decreasing linear relationship; (3)  $\beta_1 > 0, \beta_2 < 0$  and  $\beta_i = 0$ , for  $i > 2$ , reveals an inverted-U quadratic relationship between inequality and GDP per capita, indicating that high levels of income are associated with decreasing levels of inequality once a certain level of income is reached. The peak of this quadratic curve is reached at the turning point where  $z = -\beta_1/2\beta_2$ ; (4)  $\beta_1 < 0, \beta_2 > 0$  and  $\beta_i = 0$ , for  $i > 2$ , suggests a quadratic relationship in U pattern; (5)  $\beta_1 > 0, \beta_2 < 0, \beta_3 > 0$  and  $\beta_i = 0$ , for  $i > 3$ , indicates a cubic polynomial, representing the N-shaped pattern, where the inverted-U hypothesis occurs up to a certain point, from which inequality increases again. (6)  $\beta_1 < 0, \beta_2 > 0, \beta_3 < 0$  and  $\beta_i = 0$ , for  $i > 3$ , reveals a cubic polynomial, representing the inverted-N shape.

Therefore, evaluating the inverted U-shaped relationship between economic growth and income inequality for the raw data (levels) and natural logarithm forms of real GDP per capita is done at constant 2009 US dollar values, while measuring different levels of income distribution for income inequality. The data was sought for income distribution from the work of Frank (2009),<sup>4</sup> inequality measures for Gini, Artkin05, RMeanDev and Theil, Top 10 and Top 1% as put together for World Wealth and Income Database (WWID), while data on real GDP per capita was obtained from Global Financial Database (GFD).

## Results and Empirical Discussion

This section contains the results and discussion on the empirical findings from several estimations carried out. In order to achieve the research objective of investigating the inverted U-shaped relationship between economic growth and income inequality in United States, the idea of co-summability was adopted to choose the suitable model specification for the study data. The co-summability technique is built on two distinct tests of summability and balancedness as earlier discussed. Based on the idea of summability, an evaluation of balancedness was carried out i.e. the test for the order of summability of our dependent variable (income inequality) in a hypothesized model specification, is not different from that of the exogenous variables. On the other hand, if balancedness of the variables are confirmed, then it is not out of place to evaluate for co-summability i.e. to test whether the random term of the hypothesized model specification is of a lower order of summability. It is crucial to bear in mind that the model specifications confirming the balancedness and co-summability existence are probably most suitable for the data.

In Table 1, we present the estimation results of the order of summability for all the variables included in Eq. (5), as well as the corresponding 95% confidence intervals over the coverage period for specified model in Eq. (5), up to  $k = 4$ . Interestingly, the confidence intervals for the tests on real GDP per capita and on two measures of income distribution (Top 10 and

Top 1%) in levels, does not include zero, thus, rejecting the null hypothesis of summability of order zero. However, the estimated orders of summability for Atkin05, Gini, Rmeandev and Theil are in contrast very close to zero. Therefore, the null hypothesis that these income distribution measures are  $S(0)$  cannot be rejected. These results are almost identical to when log forms are used, with the exception of the linear term ( $\ln GDP$ ) which is  $S(0)$  in this case. These empirical findings give prominence to the crucial persistence of the data and presents a strong incentive for the analysis over time series properties earlier posited to be of ultimate significance when evaluating the economic growth and income inequality relationships. In relation to the integrated data, there is possibility of having spurious results, if there is failure to confirm that the specified empirical models are balanced and co-summable.

**Table 1** Estimated Order of Summability

Variables	$\hat{\beta}^*$	$I_{low}$	$I_{up}$
<i>Raw data</i>			
Atkin05	0.317	-0.156	0.791
Gini	0.298	-0.118	0.714
Rmeandev	0.327	-0.182	0.837
Theil	0.314	-0.128	0.756
Top10	1.072	0.473	1.671
Top1	0.603	0.156	1.051
GDP	0.824	0.396	1.252
(GDP) <sup>2</sup>	1.055	0.522	1.587
(GDP) <sup>3</sup>	1.287	0.641	1.934
(GDP) <sup>4</sup>	1.520	0.741	2.299
<i>Log-transformed data</i>			
Ln(Atkin05)	0.356	-0.274	0.985
Ln(Gini)	0.291	-0.150	0.731
Ln(Rmeandev)	0.360	-0.184	0.905
Ln(Theil)	0.396	-0.033	0.826
Ln(Top10)	1.069	0.489	1.649
Ln(Top1)	0.634	0.067	1.202
Ln(GDP)	0.526	-0.026	1.079
Ln(GDP) <sup>2</sup>	0.570	0.024	1.117
Ln(GDP) <sup>3</sup>	0.608	0.210	1.007
Ln(GDP) <sup>4</sup>	0.643	0.275	1.010

$\hat{\beta}^*$  represents the estimated order of summability from Eq. (4) and computed of all variables included in Eq. (5).  $I_{low}$  and  $I_{up}$  denotes lower and upper bounds of the corresponding 95% confidence intervals which are constructed using the subsampling inference method of Politis et al. (1999). All the variables have been partially detrended

In Table 2, the results of balancedness tests are contained for both levels and natural logarithms for the coverage periods in this study. It tests the null hypothesis  $H0: \beta_y - \beta_f = 0$  against the alternative  $H1: \beta_y - \beta_f \neq 0$  where  $\beta_y$  and  $\beta_f$  are the summability orders of the dependent variable  $y_t$  and the sum of the explanatory variables  $\sum_{i=1}^k z^i_t$ , respectively, in the regression given by Eq. (5). Note that the summability estimated orders  $\hat{\beta}^y$  and  $\hat{\beta}^f$  are obtained by OLS of Eq. (2), while the confidence intervals are constructed using the subsampling inference method of Politis et al. (1999). For the sampled periods, results

**Table 2** Test for balancedness

Dependent variables	Exogenous variables	$\hat{\beta}$	$I_{low}$	$I_{up}$
Atkin05	GDP	-3.043	-5.235	-0.852
Atkin05	(GDP) <sup>2</sup>	-5.770	-9.361	-2.179
Atkin05	(GDP) <sup>3</sup>	-8.424	-13.489	-3.358
Atkin05	(GDP) <sup>4</sup>	-11.047	-17.755	-4.339
Gini	GDP	-3.028	-5.004	-1.051
Gini	(GDP) <sup>2</sup>	-5.755	-9.223	-2.286
Gini	(GDP) <sup>3</sup>	-8.409	-13.497	-3.320
Gini	(GDP) <sup>4</sup>	-11.032	-17.777	-4.286
Rmeandev	GDP	-2.802	-4.629	-0.976
Rmeandev	(GDP) <sup>2</sup>	-5.529	-8.900	-2.158
Rmeandev	(GDP) <sup>3</sup>	-8.183	-13.231	-3.134
Rmeandev	(GDP) <sup>4</sup>	-10.806	-17.512	-4.100
Theil	GDP	-2.709	-4.529	-0.889
Theil	(GDP) <sup>2</sup>	-5.436	-8.705	-2.166
Theil	(GDP) <sup>3</sup>	-8.090	-12.919	-3.261
Theil	(GDP) <sup>4</sup>	-10.713	-17.163	-4.263
Top10_p	GDP	-2.941	-5.015	-0.866
Top10_p	(GDP) <sup>2</sup>	-5.667	-9.371	-1.964
Top10_p	(GDP) <sup>3</sup>	-8.321	-13.546	-3.097
Top10_p	(GDP) <sup>4</sup>	-10.944	-17.670	-4.219
Top1_ps	GDP	-3.078	-5.266	-0.890
Top1_ps	(GDP) <sup>2</sup>	-5.805	-9.589	-2.021
Top1_ps	(GDP) <sup>3</sup>	-8.459	-13.767	-3.151
Top1_ps	(GDP) <sup>4</sup>	-11.082	-17.902	-4.262
LAtkin05	L(GDP)	<b>0.006</b>	<b>-0.901</b>	<b>0.913</b>
LAtkin05	L(GDP) <sup>2</sup>	<b>-0.803</b>	<b>-2.035</b>	<b>0.429</b>
LAtkin05	L(GDP) <sup>3</sup>	<b>-1.523</b>	<b>-3.130</b>	<b>0.083</b>
LAtkin05	L(GDP) <sup>4</sup>	-2.207	-4.170	-0.243
LGini	L(GDP)	<b>-0.224</b>	<b>-1.021</b>	<b>0.572</b>
LGini	L(GDP) <sup>2</sup>	-1.034	-1.998	-0.069
LGini	L(GDP) <sup>3</sup>	-1.754	-3.093	-0.415
LGini	L(GDP) <sup>4</sup>	-2.437	-4.133	-0.741
LRmeandev	L(GDP)	<b>-0.066</b>	<b>-0.875</b>	<b>0.743</b>
LRmeandev	L(GDP) <sup>2</sup>	-0.875	-1.708	-0.042
LRmeandev	L(GDP) <sup>3</sup>	-1.595	-2.797	-0.393
LRmeandev	L(GDP) <sup>4</sup>	-2.279	-3.833	-0.724
LTheil	L(GDP)	<b>0.076</b>	<b>-0.872</b>	<b>1.024</b>
LTheil	L(GDP) <sup>2</sup>	<b>-0.733</b>	<b>-1.650</b>	<b>0.184</b>
LTheil	L(GDP) <sup>3</sup>	-1.453	-2.643	-0.264
LTheil	L(GDP) <sup>4</sup>	-2.137	-3.700	-0.574
LTop10_p	L(GDP)	<b>-0.093</b>	<b>-0.836</b>	<b>0.650</b>
LTop10_p	L(GDP) <sup>2</sup>	-0.902	-1.696	-0.108
LTop10_p	L(GDP) <sup>3</sup>	-1.623	-2.760	-0.485
LTop10_p	L(GDP) <sup>4</sup>	-2.306	-3.850	-0.762

**Table 2** (continued)

Dependent variables	Exogenous variables	$\hat{\beta}$	$I_{low}$	$I_{up}$
LTop1_ps	L(GDP)	<b>0.034</b>	<b>-0.873</b>	<b>0.941</b>
LTop1_ps	L(GDP) <sup>2</sup>	<b>-0.775</b>	<b>-1.652</b>	<b>0.102</b>
LTop1_ps	L(GDP) <sup>3</sup>	-1.495	-2.738	-0.253
LTop1_ps	L(GDP) <sup>4</sup>	-2.179	-3.854	-0.503

$\hat{\beta}_T = \hat{\beta}_y - \hat{\beta}_f$ ,  $\hat{\beta}_y$  and  $\hat{\beta}_f$  represent the estimated order of summability of the dependent variable and the sum of the explanatory variables respectively. All the variables have been partially detrended. It tests the null hypothesis  $H_0 : \beta_y - \beta_f = 0$  against the alternative  $H_1 : \beta_y - \beta_f \neq 0$  where  $\beta_y$  and  $\beta_f$  are the summability orders of the dependent variable  $y_t$  and the sum of the explanatory variables  $\sum_{i=1}^k z_{it}$ , respectively, in the regression given by Eq. (5).  $\hat{\beta}_y$  and  $\hat{\beta}_f$  are obtained by OLS of Eq. (2).  $I_{low}$  and  $I_{up}$  represents lower and upper bounds of the corresponding 95% confidence intervals which are constructed using the subsampling inference method of Politis et al. (1999)

The bold values indicate linear relationship between income inequality and economic growth for the United States

reveal that balancedness is only confirmed when data are taken in logarithms, but with a maximum polynomial order that differs from one variable to another; until  $k = 3$  for Atkin05, that is, under linear, quadratic and cubic polynomial specifications, since zero is included in the corresponding confidence intervals; until  $k = 2$  for Theil and Top 1%;  $k = 1$  for Gini, Rmeandev and Top 10%. Consequently, based on these results, it is of no use to further consider the data in levels (raw data). In a nutshell, the null hypothesis of balanced specifications cannot be rejected for the specified models.

In addition, Table 3 reports the results for co-summability tests of the variables taken in natural logarithms form. Note that this table shows only the regressions for which the balancedness is achieved. The testing procedure is a residual based test for the null hypothesis of strong co-summability  $H_0 : \beta_\varepsilon = 0$  against the alternative  $H_1 : \beta_\varepsilon \neq 0$  where  $\beta_\varepsilon$  is the summability order of the residuals obtained using the ordinary least squares (OLS) estimation method of Eq. (5). Note that the summability estimated order  $\hat{\beta}_\varepsilon$  is obtained by OLS of Eq. (4), while the confidence intervals are constructed using the subsampling inference method of Politis et al. (1999). For the log-transformed data, results show that co-summability is not rejected for all considered specifications except the linear form for some variables; the rejection is observed only for Theil in the case of linear form with deterministic trend and for Top 10 and Top 1% in the case of a linear form both with and without deterministic trend.

Based solely on balancedness and co-summability results, there is some ambiguity about the adequate form to use for each variable. Indeed, there exists more than one potential specification for some variables; linear, quadratic or cubic form for Atkin05; linear or quadratic form for Theil. For Top 1%, quadratic form seems to be the most appropriate (see Tuominen 2016b) while the linear form is adequate for Gini and Rmeandev. For Top 10%, Co-summability is however rejected. In order to select, for each inequality measure, the most appropriate specification among those for which both balancedness and co-summability are achieved, we use three fitness tests for model selection; Akaike information criteria (AIC), Schwarz information criteria (BIC) and the Likelihood Ratio Test (LRT). As for the comparison between AIC and BIC, we observe that the selection results of BIC are identical with AIC, with the exception for Atkin05 inequality measure. In the case of Atkin05,



**Table 3** Test for co-summability

Dep. Var.	L(Atkin05)	L(Atkin05)	L(Atkin05)	L(Atkin05)	L(Atkin05)	L(Gini)	L(Gini)	L(Rme andev)	L(Rme andev)	
1	-3.453***	2.541*	38.306***	40.842***	-90.003	-75.259	-2.123***	1.191*	-1.756***	2.199**
T	-	0.016***	-	-0.006*	-	-0.005	-	0.009***	-	0.011***
L(GDP)	0.193***	-0.501***	-8.453***	-9.167***	31.366	26.856	0.145***	-0.239***	0.142***	-0.316***
L(GDP) <sup>2</sup>	-	-	0.446***	0.495***	-3.663	-3.219	-	-	-	-
L(GDP) <sup>3</sup>	-	-	-	-	0.141*	0.127	-	-	-	-
$\hat{\beta}_\varepsilon^*$	0.329	0.414	-0.070	-0.479	-0.087	-0.416	0.307	0.396	0.283	0.378
$I_{b,w}$	-0.361	-0.014	-0.933	-1.559	-0.814	-1.269	-0.297	-0.117	-0.430	-0.133
$I_{ap}$	1.020	0.843	0.794	0.601	0.639	0.437	0.912	0.909	0.996	0.888
AIC	-0.359	-0.516	-1.296	-1.307	-1.311	-1.315	-1.794	-2.008	-1.319	-1.503
BIC	-0.305	-0.435	-1.216	-1.200	-1.204	-1.182	-1.740	-1.927	-1.266	-1.423
LRT <sub>1</sub>	17.057***	91.984***	94.993***	95.403***	97.819***	22.508***	-	-	-	19.652***
LRT <sub>2</sub>	-	-	3.009*	3.419*	5.835*	-	-	-	-	-
Dep. Var.	L(Theil)	L(Theil)	L(Theil)	L(Theil)	L(Top10)	L(Top10)	L(Top1)	L(Top1)	L(Top1)	
1	-2.355***	7.509***	72.253***	78.479***	-0.918***	5.465***	-1.826***	6.963***	61.463***	65.898***
T	-	0.027***	-	-0.014***	-	0.017***	-	0.024***	-	-0.010***
L(GDP)	0.179***	-0.963***	-15.268***	-17.020***	-0.002	-0.741***	-0.015	-1.033***	-13.119***	-14.367***
L(GDP) <sup>2</sup>	-	-	0.796***	0.917***	-	-	-	0.675***	0.761***	-
L(GDP) <sup>3</sup>	-	-	-	-	-	-	-	-	-	-
$\hat{\beta}_\varepsilon^*$	0.408	0.536	0.022	-0.075	1.082	0.625	0.656	1.722	0.446	0.645
$I_{b,w}$	-0.159	0.108	-0.734	-0.892	0.440	0.244	0.050	0.832	-0.241	-0.122
$I_{ap}$	0.975	0.964	0.777	0.742	1.724	1.006	1.262	2.612	1.133	1.412
AIC	0.661	0.509	-0.555	-0.627	-1.053	-1.494	0.343	0.174	-0.845	-0.886
BIC	0.714	0.589	-0.475	-0.520	-1.000	-1.414	0.397	0.254	-0.765	-0.779
LRT <sub>1</sub>	16.62***	118.74***	127.65***	127.65***	44.30***	18.29***	116.10***	18.29***	116.10***	122.05***

**Table 3** (continued)

Dep. Var.	L(Theil)	L(Theil)	L(Theil)	L(Theil)	L(Top10)	L(Top10)	L(Top10)	L(Top1)	L(Top1)
$LRT_2$				8.910***					5.953**

$\hat{\beta}_f^*$  represents the estimated order of summability of the residual, after subtracting the first observation, calculated from the regression (5) as proposed by Berengue-Rico and Gonzalo (2013), while  $I_{low}$  and  $I_{up}$  represents lower and upper bounds of the corresponding 95% confidence intervals which are constructed using the subsampling inference method of Politis et al. (1999). All residuals series have been partially demeaned.  $LRT_1$  and  $LRT_2$  are the likelihood ratio tests of the null hypotheses of linear and quadratic forms (without trend), respectively

The bold values indicate linear relationship between income inequality and economic growth for the United States

\*\*\*, \*\* and \* represent significance at the 1, 5 and 10% levels respectively

despite the fact that cubic form with deterministic trend is selected by the AIC criterion, the likelihood ratio test confirms the result of the BIC criterion by not rejecting the null hypothesis of quadratic form without deterministic trend at conventional 5% level. To summarize, our results indicate that the relationship between income and inequality has generally either linear or quadratic form. Indeed, out of six measures of inequality used in this study, three among them give evidence to a quadratic relationship; quadratic form without deterministic trend for Atkin05; and quadratic form with deterministic trend for Theil and Top 1%. The measures of inequality providing evidence in favor of linear relationship with deterministic trend are Gini and Rmeandev. In addition, by analyzing the signs of the coefficient estimates for the selected quadratic regressions we found that  $\beta_1 < 0$  and  $\beta_2 > 0$ , which implies a quadratic relationship in U pattern. Hence, there is no evidence of an inverted U-shaped relationship between income and inequality in United States.

Consequently, based on the empirical results and current findings, the researchers conclude as in Hsing and Smyth (1994) and Jacobsen and Giles (1998) that the Kuznets inverted U-shaped hypothesis is not applicable to United States. This implies that relative to Hsing and Smyth (1994) and Jacobsen and Giles (1998), using long and very recent data with advanced econometric techniques that capture nonlinearity in the long-run relationship between income inequality and economic growth, does not help with evidence in support of the inverted U-shaped curve theory.

## Conclusion

This study employed more sophisticated econometric techniques to investigate the existence of the popular Kuznets inverted U-shaped hypothesis in the long-run equilibrium relationship between economic growth and income inequality at various measures for United States. Motivated by the plethora of controversial arguments and differing conclusions regarding the relationship between growth and inequality levels, this study employed long and very recent data to capture transformation processes of the sampled country, using the idea of co-summability, which is proposed to analyze nonlinear long-run relations among stochastic processes. The empirical results and findings, however, present no evidence in support of the Kuznets inverted U-shape for United States.

The findings challenge some of the prevailing conclusions regarding the existence of an inverted U-shaped relationship between economic growth and income inequality in the United States. However, this is not a claim that high income inequality level should not bother the policymakers or that income inequality in the short-run may not be harmful to growth. Alternatively, emphasis is placed on the absence of evidence for nonlinear methodology for the relationship between economic growth and income inequality. If the long-run relationship between economic growth and income inequality implies causality, then current empirical findings have policy implications, such that a country with negligible income inequality can influence its growth by broadening its income inequality level, while one with a high income inequality can enhance its growth by lowering its income inequality level. With the confirmation of linear form at some point, there seems to be a relationship between changes in income inequality and level of income. Variations in income inequality, whatever the direction may be, are related with lower and/or higher level of income.

However, since this model did not capture a relationship of causality, then such policy recommendations should be taken with cautiousness.

## Notes

<sup>1</sup>For interested reader see the work of Kuznets (1955) and Anand and Kanbur (1993).

<sup>2</sup>In this study we use income per capita and economic growth synonymously.

<sup>3</sup>There are many reasons why income inequality would negatively or positively influence

<sup>4</sup>For an exposition on the estimation of this series and file including percentile threshold see Frank, Sommeiller–Price and Saez. Interested reader for further explanation on estimation of other measures of income share or distribution should see Frank (2009).

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