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Linear and Non-linear Relationships Between Growth, Inequality, and Poverty in a Panel of Latin America and the Caribbean Countries: A New Evidence of Pro-poor Growth

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Abstract The relationships between growth, inequality, and poverty is widely discussed area in the development economics, which fairly overcrowded by linear and non-linear growth components, however, while developing an index for pro-poor growth, the non-linearity portion of growth has been widely ignored that address in this study by using a panel of 18 selected Latin America and the Caribbean countries from 1981 to 2012. The study proposed a new measure of pro-poor growth index, called 'Poverty Interdependence Growth Index (PIGI)', which further extended in order to satisfy the monotonicity criterion of pro-poor growth and poverty reduction, called 'Poverty Interdependence Equivalent Growth Rate (PIEGR)'. The results show that the impact of per capita survey income and income inequality on poverty measures are 'linear' in nature when controlling the non-linear components of growth, however, if this assumption is relaxed, the study doesn't established either 'U-shaped' and/or 'asymptotic' relationship between the variables. The non-poverty measures including educational expenditures, health expenditures and population growth significantly increases F–G–T measures of poverty. The estimates of PIGI and PIEGR reveal that out of 18 countries, there are 4 countries shows highly pro-poor growth, 11 countries shows negative pro-poor growth index (i.e., immiserizing growth scenarios, where a positive growth increases poverty), and the remaining 3 countries shows pro-rich. The study illustrates that our new measure of pro-poor growth index fairly provides conclusive findings.

Keywords Pro-poor growth · Non-linear growth components · Income inequality · Panel random effect · System panel GMM

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1 Introduction

Pro-poor growth is one of the widely discussed areas in the development literature. The seminal work of Kuznets (1955) considered one of the foundation works for this debate, which later down focused by number of scholars and international agencies that coined the word i.e., 'broad-based growth' and 'pro-poor growth' (see, Chenery et al. 1974; World Bank 1990; ADB 1999; Ravallion 2004 etc.). Afterward, the debate has prolonged and spread in an academic and research arena and till now it consider the most impulsive and pragmatic contest among the development economists. World Bank (2011) segregated the pro-poor growth measures into three broad categories, i.e., (1) the studies falls in the 'aggregate measures' of pro-poor growth including 'Growth Incidence Curve (GIC)' suggested by Ravallion and Chen (2003), and 'decomposition of growth and inequality' by Datt and Ravallion (1992), (2) the study falls in 'absolute measures' of pro-poor growth including 'rate of pro-poor growth' suggested by Ravallion and Chen (2003), and (3) the studies falls in the 'relative measures' of pro-poor growth including 'poverty bias of growth' by McCulloch and Baulch (2000), 'pro-poor growth index' by Kakwani and Pernia (2000), 'poverty equivalent growth rate' by Kakwani and Son (2002), and 'poverty growth curve' by Son (2003).

1.1 Discussion on Income and Non-Income Poverty

The debate on monetary/income and non-income (human) poverty, both widely pronounced in poverty research agenda for inclusive growth. The advocates of income poverty approach argued that poverty is based on measure of monetary/income that evaluate with it certain threshold income levels, if income poverty surpasses the threshold level, we do not consider a person to be a poor while reverse is reserve for poor. Though, the classical definition of poverty served many purpose in materialistic world, however, it consider as an indirect approach to measure poverty. The number of studies measured pro-poor growth by monetary indicators i.e., income or consumption, for example, Ravallion and Chen (2003) measured the rate of pro-poor growth by using absolute terms and confirmed that economic growth supports the poor and reduce poverty, while Kakwani and Pernia (2000) and McCulloch and Baulch (1999) measured it by relative concepts, i.e., growth proportionally benefits the poor more than the non-poor. The poverty is multidimensional phenomenon; therefore, the income alone does not truly translate the poverty reduction and pro-poor growth reforms. The direct measure of poverty is non-monetary measures that look directly at the bundle of goods and it measures what people are lacking for it. It contains some basic necessities goods like food, shelter, clothing, basic education, healthcare facilities, safe water, good sanitation, etc. Klasen (2008) introduced the number of non-monetary indicators in pro-poor growth scenario by using a country case study of Bolivia and utilized 'Growth Incidence Curve (GIC)' approach to country's non-monetary indicators including education, health, and nutrition. The findings come to the following conclusion that income growth was relatively pro-poor and strongly oppose to the absolute pro-poor growth, while in non-income dimensions, growth generally in favor of the poor in absolute sense and shows some considerable improvement in the education, health, and nutritional indicators at countrywide. Grosse et al. (2008) further extended the non-income dimensions of pro-poor growth indicators for Bolivia by using both the GIC approach and poverty equivalent growth rate, and evaluated different basket of goods contain education, health, and nutrition during 1989–1998. The results generally supported the relative sense

of pro-poor growth using both the monetary and non-monetary income approach, while it's weakly supported in absolute sense. The overall results conclude that poverty either based on income approach and/or non-income approach shows considerable improvement in different dimensions of poverty, which is generally favorable in the context of Bolivia. Tran et al. (2015) identified the disparities between monetary and non-monetary poverty dimensions by using the Vietnam's panel data for 2007, 2008, and 2010. The results conclude that the person who have a greater market accessibility to get more benefits from monetary income as compared to the others, as initial phase of development largely contributed to the higher rate of income poverty reduction by higher growth, however, it is not a sufficient condition that the same person perform well in non-income poverty dimensions, as the person required more additional efforts and time to perform well in non-income dimensions. Zaman (2015) expanded the non-income poverty measures in 21 welfare indicators by using four household surveys, i.e., 2002, 2006, 2008, and 2011. The results show the significant differences between both the poverty measures in terms of aggregation and distributional patterns. The results supported largely relative pro-poor growth in non-income dimensions and weakly supported the absolute pro-poor growth in few non-income dimensions. Bader et al. (2016) further identified the significant differences between the monetary income and multidimensional poverty (MDP) measures by using the Lao household data of 2007–2008. The results of the study show some interesting finding in the country context, i.e., the study identified a large pool of household are "overlooked poor" which were not identified by monetary income, while it is identified in MDP measures. The higher deprivation score is in education and nutrition identified the "overlooked poor" in MDP measures while monetary income failed to identify the poor, which lead to clear opposite direction between the two poverty measures. The results further provoked that the correlation between MDP and income poverty is limited, which further confirmed that income poverty does not serve as a true proxy for MDP measures and vice versa.

1.2 Relationships Between Growth, Inequality and Poverty

The relationship between poverty, inequality and development traced by the classical work of Ahluwalia (1976), which presented the crucial facts regarding the three above stated elements in a cross-country setting, and proclaimed that relative inequality increases along with an increase in economic development, which declines at the later stages of development. This relationship is widely exhibit longer in the poorest countries group. This causal relationship is attributed with the educational attainment, flexible labor market, and population reduction strategies that helpful to reduce relative inequality by economic development across nations. Bourguignon (2004) interlinked the poverty, growth, and inequality in a functional form of triangular mode and concluded that wealth redistribution policies from rich to poor may tend to improve economic growth through the channel of flexible credit market. The redistributive policies matter for reduction in general poverty by increasing country's income, which further improves the income transfer channel for pro-equality growth. Heshmati (2004) examined the causal relationships between growth, inequality, and poverty by using the longitudinal data set of countries with longer time period and found the convergence in the country's per capita income, while divergence is presence in income inequality data set, which is attributed due to homogeneity in the panel of advanced countries and heterogeneity among less developed countries. The results further indicate the heterogeneity in the policy propositions for poverty reduction, as income inequality considerably affect the process of poverty reduction, which further

affected the country's development process. In industrialized countries, the wage differential gap substantially increases by increasing trade liberalization policies, while in developing countries; trade liberalization policies support the labor market to reduce the wage inequality. Finally, the study comes to the conclusion with the global U-shaped Kuznets curve. Ravallion (2001) discussed the data limitations across cross-country correlation that hides the development phase of poor in developing countries. The results enforced the need of distribution—corrected rate of growth in average income that helpful to expedite the process of pro-poor growth and poverty reduction. The study suggested micro analysis of growth and income redistribution that would support growth-oriented policies across countries. Adams (2004) selected the data set of 60 developing countries and confirmed that economic growth promotes pro-poor growth policies by reduction in the poverty in the absence of income inequality, however, the study pointed out the economic efficiency of growth variables, which previously used different variables in diverse economic settings. The results come to the conclusion that per capita GDP is not a significant variable that translated into pro-poor growth and poverty reduction, while changes in survey income considered the significant predictor that have a considerable impact on poverty reduction across countries. Dollar and Kraay (2002) considered the large panel of 92 countries with a 40 year time period and found that trade openness, economic stability, fiscal instruments, and private property rights considerably increases the income of the residents and does not discriminate rich and poor in a country, which exhibit that economic policies may not trickle down to the poor directly, while its indirectly transferred benefits of economic growth to the poor as received initially richer for the dominating side. The growth-enhancing strategies would be beneficial to support the process of pro-poor growth and poverty reduction across nations. Ravallion (2005) discussed the two stand points of poverty—inequality trade off by analyzing the 70 developing and transition economies in 1990s, i.e., the first point is the significant trade-off between lower poverty with lower relative inequality, and the second point is the trade -off between absolute inequality and poverty, which is associated between rising inequality and falling poverty. The study, in general, concluded that there is not a significant trade-off between absolute poverty and relative inequality due to low correlation between income and changes in the relative inequality. Therefore, it is advisable to see the absolute inequality with reference of poverty reduction for policy formulation. Dollar et al. (2015) collected the larger data set of 115 countries with 40 year data period and concluded that income inequality is less sensitive to the growth, which implies that cross-country variation in changes in social welfare is largely attributed to growth in average incomes.

The overall discussion confirmed the strong correlation between growth, poverty and inequality that widely recognized the trickledown theory in favor of poor under macroeconomic factors. This debate is prolonged in cross-country analysis which supported largely pro-poor growth framework under judicious income distribution. The policy to support the poor in equitable mode confined the idea of pro-equality growth arguments across the globe.

1.3 Pro-poor Growth Scenario

This study proposed a new measure of pro-poor growth index, called 'Poverty Interdependence Growth Index (PIGI)', which included both the linear and non-linear growth components, which previous ignored in the existing pro-poor growth indices, for example, McCulloch and Baulch (2000) proposed 'poverty bias of growth (PBG)', which mainly focused on reducing inequality. The PBG index captured 'pure growth effect' and 'pure

inequality effect' in the absence of one and another. This index has some limitations, as higher the value of PBG does not necessarily imply greater poverty reduction because changes in poverty depends upon pure growth effect. In addition, the PBG mainly driven by 'linear symmetric poverty decomposition' as suggested by Kakwani (2000), while both the studies completely ignored the non-linear adjustments of growth phases that has a considerable impact on the pro-poor growth reforms. Kakwani and Pernia (2000) proposed 'pro-poor growth index (PPGI)' that falls under the strict definition of pro-poor growth with relative approach. This index based on poverty elasticity of growth and inequality and compute total poverty elasticity, than its relative to the growth elasticity to form PPGI. This index suggested certain value judgment threshold levels for assessment i.e., whether the growth phase was poor or anti-poor, as if the PPGI value greater than the unity, the growth process considered pro-poor or else anti-poor. This index has some limitations, as it does not satisfied the monotonicity criterion of poverty reduction, while it does not account the non-linear symmetric decomposition of poverty to capture the later stages of economic development towards poverty reduction. Kakwani and Son (2008) proposed another index of pro-poor growth, called 'poverty equivalent growth rate (PEGR)' that captures the gains and losses of growth via distribution channel. The PEGR satisfied monotonicity criterion of pro-poor growth and poverty reduction. The PEGR is pro-poor (anti-poor), when the value of PEGR is greater (lesser) than the value of actual growth rate between two surveys period. This index although satisfied both necessary and sufficient condition of pro-poor growth and poverty reduction, however, non-linearity symmetric poverty decomposition and distribution channel in the later stages of economic development is overlooked again. Similarly, the other poverty reduction curves including 'Growth Incidence Curve' and 'Poverty Growth Curve' both based on stochastic dominance curve while ignoring poverty line and poverty measures.

The PIGI and PIEGR is based on linear (see, Kakwani and Pernia 2000; Kakwani and Son 2008; Son and Kakwani 2008) and non-linear systematic poverty decomposition (see, McKinley 2009; Zaman 2016) combined together to form a new and relative measures of pro-poor growth index (authors' self extracted), which satisfied monotonicity criterion of pro-poor growth and poverty reduction at the later stages of economic development, while it falls in the strict definition of pro-poor growth under relative domain of growth index. This methodology is applied on 18 selected Latin America and the Caribbean countries by using international poverty line of US $1.90 per day. The study first estimated the long-run relationship between growth, inequality, poverty, and human poverty measures under the premises of linear and non-linear growth components, by using panel least square regression, panel random effect, and system panel GMM estimator in a panel of selected Latin America and the Caribbean countries for the period of 1981–2012. Later on, the study using the same concept and extended non-linear symmetric poverty decomposition in the pro-poor growth index, and form a new, stable, and relative measure of pro-poor growth index called 'poverty interdependence growth index' and 'poverty interdependent equivalent growth rate', which applied on individual countries of 18 selected Latin America and the Caribbean countries to assess whether the economic development at the later stages has impeding any impact on poverty reduction. For this reason, the study included non-linearity component of growth in an existing pro-poor growth indices.

2 Data Source and Methodological Framework

The following variables has been used in order to examine the long-run relationship between growth, inequality, poverty, and non-poverty measures, i.e., average monthly per capita income expenditures, Gini index (a measure of inequality), Foster–Greer–Thorbecke (F–G–T) indices including poverty headcount, poverty gap, and squared poverty gap; non-poverty measures include children out of school, expenditures on primary and secondary education, life expectancy at birth, infant mortality rate, and population growth in a panel of 18 selected Latin America and the Caribbean countries, namely, Argentina-Urban (data set from 1991 to 2013), Belize (1993–1999), Bolivia (1990–2013), Brazil (1981–2013), Chile (1987–2013), Columbia-Urban (1988–1991), Costa Rica (1981–2013), Dominican Republic (1986–2013), El Salvador (1991–2013), Guatemala (1986–2011), Jamaica (1988–2004), Mexico (1989–2012), Nicaragua (1993–2009), Panama (1989–2013), Paraguay (1990–2013), Peru (1997–2013), Uruguay-Urban (1992–2005), and Venezuela (1981–2006). The unified international poverty line i.e., US $1.90 per day on the basis of purchasing power parity (PPP)—2005, has been set out for the selected Latin America and the Caribbean countries. The data for poverty, income, and income inequality is taken from *POVCALNET* published by World Bank (2015a), while the data for educational expenditures, health expenditures, and population growth is taken from World Development Indicators published by World Bank (2015b). Table 1 shows the list of variables and their descriptions for ready reference.

The study started with the systematic link developed by Bourguignon (2004) regarding the poverty-inequality-growth triangle i.e.,

$$\text{Change in Poverty} \equiv \text{F}(\text{Growth}, \text{Inequality}, \text{change in Distribution}) \tag{1}$$

which further annoying compliance by McKinley (2009) and suggested the determinants of poverty reduction specification under cross-sectional regression settings i.e.,

$$\begin{aligned}\text{Poverty reduction} \equiv f(&\text{Growth}, \text{Inequality}, \text{Income per capita lagged}, \text{Gini coefficient lagged},\\ &\text{Interaction between per capita income and change in inequality})\end{aligned} \tag{2}$$

This study compliment the McKinley (2009) specification of determinants of poverty reduction by including square of income inequality and square of per capita income instead of lagged per capita income and lagged Gini coefficient to determine both the linear and non-linear growth components in the poverty-growth model specifications i.e.,

$$\ln(p)_{i,t} = \beta_0 + \beta_1 \ln(y)_{i,t} + \beta_2 \ln(g)_{i,t} + \beta_3 \ln(y)^2_{i,t} + \beta_4 \ln(y \times g)_{i,t} + \beta_5 \ln(g)^2_{i,t} + \beta_6 \ln(\gamma)_{it} + \varepsilon_{i,t} \tag{3}$$

where ‘p’ indicates F–G–T poverty indices including poverty headcount (p_0), poverty gap (p_1), and severity of poverty (p_2); ‘y’ indicates mean per capita monthly income expenditure from survey, ‘g’ indicates Gini index, γ indicates non-poverty measures (including children out of school, primary and secondary education expenditures, life expectancy at birth, infant mortality rate, and population growth), ‘ln’ indicates natural logarithm, ‘i’ indicates 18 selected Latin America and the Caribbean countries, ‘t’ indicates different household integrated countrywide surveys in a range between 1981 and 2013, and ε is the white noise error term.

Table 1 List of variables

Variables	Symbol	Measurement
Poverty headcount	P_0	%
Poverty gap	P_1	%
Square poverty gap	P_2	%
Gini coefficient	G	%
Income	Y	Average monthly per capita income expenditures on the basis of 2005 purchasing power parity
Children out of school	COOS	% Of primary school age
Expenditures on primary education	EPE	% Of government expenditure on education
Expenditures on secondary education	ESE	% Of government expenditure on education
Life expectancy at birth	LEB	Years
Infant mortality rate	IMR	Per 1000 live births
Population growth	POPG	Annual %

The coefficient β_1 and β_2 shows the linear component of growth and inequality, while β_3–β_5 shows the non-linear growth and inequality components in Eq. (3). If $\beta_1 < 0$ and $\beta_2 > 0$, it implies that the impact of economic growth and income inequality on poverty would be 'negative linear', while, if $\beta_1 > 0$ and $\beta_2 < 0$, it implies that the relationship would be 'positive linear'. On the other way around, If $\beta_3 > 0$, $\beta_4 < 0$, and $\beta_5 > 0$, while linear terms kept constant, it implies that the relationship between economic growth and poverty would be 'U-shaped', while reverse is true in case of 'inverted U-shaped' relationship between poverty and economic growth under the premises of rising income inequality. The relationship would be either 'positive asymptotic' when $\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 > 0$, $\beta_4 < 0$ and $\beta_5 > 0$, while it would be 'negative asymptotic' for the case i.e., $\beta_1 < 0$, $\beta_2 > 0$, $\beta_3 > 0$, $\beta_4 < 0$, and $\beta_5 > 0$. Finally, the relationship would be either 'positive inverted asymptotic', if and only if, $\beta_1 > 0$, $\beta_2 < 0$, $\beta_3 < 0$, $\beta_4 > 0$, and $\beta_5 < 0$, while reverse is true for 'negative inverted asymptotic; i.e., $\beta_1 < 0$, $\beta_2 > 0$, $\beta_3 < 0$, $\beta_4 > 0$, and $\beta_5 < 0$. In conclusion, Eq. (3) would also indicate whether the relationship between growth, inequality and poverty holds 'linear' relationship, 'U-shaped' relationship, and/or 'asymptotic' relationship in a panel of countries. Figure 1 shows the plots of level data for ready reference.

The study employed panel OLS regression that ignores the cross-country-time-invariant characteristics, while after confirmation the appropriate model specification by Hausman test, the study used panel random effect regression that incorporates the time invariant characteristics between the selected countries. Equation (4) shows the panel random effect regressions' model specification i.e.,

$$\ln(p)_{i,t} = \beta_0 + \beta_1 \ln(y)_{i,t} + \beta_2 \ln(g)_{i,t} + \beta_3 \ln(y)^2_{i,t} + \beta_4 \ln(y \times g)_{i,t} + \beta_5 \ln(g)^2_{i,t} + \beta_6 \ln(\gamma)_{it} + \tau_{i,t} + \varepsilon_{i,t} \quad (4)$$

where τ absorb time variant characteristics among the panel of selected countries.

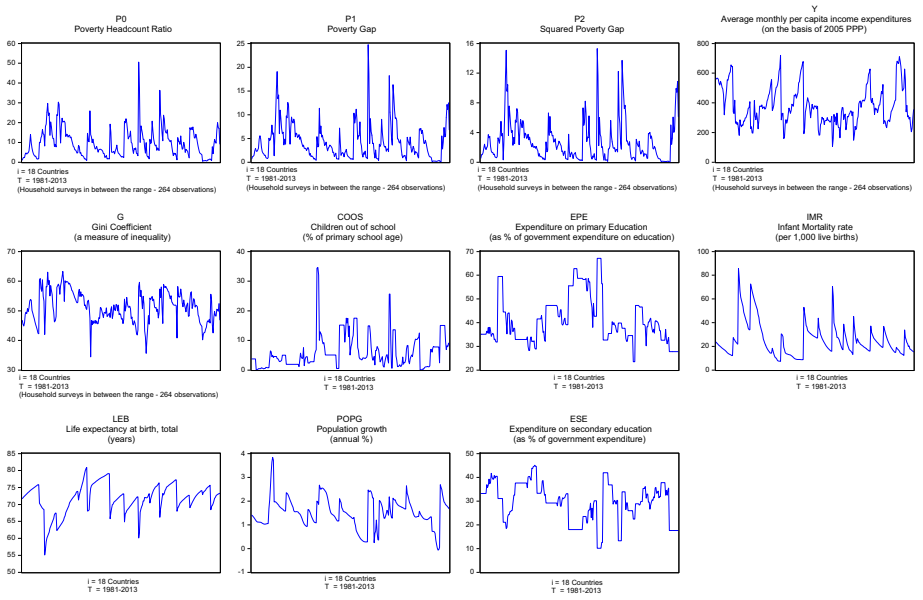

Fig. 1 Plots of the level data. *Source*: World Bank (2015a, b)

The study further employed 'system panel Generalized Method of Moments (GMM) estimator', which addresses both the serial correlation problem and possible endogeneity among the regressors. The study adopted the Arellano and Bond (1991) of GMM estimator that includes lagged dependent variable along with lagged explanatory variables in difference operator to eliminate country specific differences by appropriate instrumental list. Equation (5) shows the Arellano–Bond model specification i.e.,

$$\ln(p)_{i,t} = \beta_0 + \beta_1 \ln(p)_{i,t-1} + \ln(y)_{i,t} + \beta_2 \ln(g)_{i,t} + \beta_3 \ln(y)^2_{i,t} + \beta_4 \ln(y \times g)_{i,t} + \beta_5 \ln(g)^2_{i,t} + \beta_6 \ln(\gamma)_{it} + z_{i,t} + \varepsilon_{i,t} \quad (5)$$

where 'z' indicates lagged explanatory variables as an instrumental list.

In addition, Arellano–Bond model specifications gives certain other diagnostic tests including Sargan–Hansen J-statistic for validating the instrumental lists, while AR(1), and AR(2) test used for detecting serial correlations at first difference estimator. After obtaining the parameter estimates, the study proposed a new measure of pro-poor growth index, called 'Poverty intensive Growth Index (PiGI)', which are based upon both linear and non-linear growth components.

Pro-poor growth definition falls in two broad categories, i.e., general definition of pro-poor growth and strict definition of pro-poor growth. In general, pro-poor growth defined as growth that benefits/supports the poor in terms of poverty falls, while the proponents of strict definition argue that pattern of growth and distribution of income matters where poverty declines. Ravallion and Chen (2003) support the general definition of pro-poor growth, while Kakwani and Pernia (2000), Son (2004) and Kakwani and Son (2008) etc. supports the strict definition of pro-poor growth. Son (2004) and Ravallion and Chen (2003) supports the first order dominance condition for poverty reduction where poverty line and poverty measures does not matter, while Kakwani and Pernia (2000) and Kakwani

and Son (2008) etc. created the rate of index for poverty reduction under the national/global poverty line and F–G–T measures of poverty measure. The pro-poor growth index proposed by Kakwani and Pernia (2000) falls in the monotonicity criterion, as it includes both the growth component and the mechanism to share the income flow from rich to the poors via direct and indirect linkages.

The 'poverty interdependence growth index' based on strict definition of pro-poor growth, where economic growth, judicious income distribution, and 'joint interdependence' of growth and inequality matters for poverty reduction that trickle down to the poor as compared to the non-poor. More specifically, the proposed index executes the 'full approach' of pro-poor growth, as growth process judged by linear and non-linear growth components. This index satisfied the monotonicity criterion of pro-poor growth reduction, as it implies both the linear and non-linear part of economic growth and income distribution that satisfied both the necessary and sufficient condition of poverty reduction. The study further extended the poverty interdependence growth index into poverty interdependence equivalent growth rate that captured the gains/losses of growth rate due to inequality change. As Kakwani and Son (2008) argued that gains reflect pro-poor growth, while losses imply pro-rich growth or anti-poor growth. This index supports the fundamentals of poverty equivalent growth rate under the premises of non-linear growth and inequality components in it. The poverty interdependence growth index (PIGI) comprises both the linear and non-linear growth-inequality components to judge whether the growth process is pro-poor or anti-poor i.e.,

(i) Linear and non-linear growth components under joint dependence of growth and inequality:

$$\eta = \frac{\Delta p_\alpha / p_\alpha}{\Delta y / y} + \frac{\Delta p_\alpha / p_\alpha}{\Delta y^2 / y^2} + \frac{\Delta p_\alpha / p_\alpha}{\Delta (y \times g)/y \times g} \tag{i}$$

(ii) Linear and non-linear inequality components under joint dependence of growth and inequality:

$$\zeta = \frac{\Delta p_\alpha / p_\alpha}{\Delta g / g} + \frac{\Delta p_\alpha / p_\alpha}{\Delta g^2 / g^2} + \frac{\Delta p_\alpha / p_\alpha}{\Delta (y \times g)/y \times g} \tag{ii}$$

(iii) Total poverty elasticity:

$$\delta = \eta + \zeta \tag{iii}$$

(iv) Poverty Interdependence Growth Index (PIGI):

$$\varphi = \frac{\delta}{\eta} \tag{iv}$$

(v) Poverty Interdependence Equivalent Growth Rate (PIEGR):

$$\gamma = \gamma^* \times \varphi \tag{v}$$

where η is the linear and non-linear growth elasticity under the presence of joint dependence of growth and inequality, ζ is the linear and non-linear inequality elasticity under the presence of joint dependence of growth and inequality, δ is the total poverty elasticity, φ is the poverty intensive growth index, γ is poverty intensive equivalent growth rate, α is F-G-T measures of poverty i.e., poverty headcount (p_0), poverty gap (p_1), and squared poverty gap (p_2), and γ^* is the actual growth rate between two time period.

This index is relatively better and wide-ranging in terms of explaining changes in poverty over time, which derived on the basis of four main elements i.e., (i) Sum of linear and non-linear poverty elasticity of growth, while inequality includes as an interactive term with the economic growth, (ii) Sum of linear and non-linear poverty elasticity of inequality, while economic growth includes as an interactive term with the income inequality, (iii) Total poverty elasticity, which is the sum of (i) and (ii) elements, (iv) Poverty interdependence growth index is the formulation of (iii) relative to element (i), and finally, (v) Poverty interdependence equivalent growth rate is the joint product of actual growth rate and poverty interdependence growth index (which implies gains/losses of economic growth). This index satisfied the monotonicity criterion of pro-poor growth index under the non-linear growth components and presented the results in a more generalized form of poverty reduction.

3 Results

Table 2 shows the descriptive statistics and correlation matrix among the growth, inequality poverty, and non-poverty measures in a panel of selected Latin America and the Caribbean countries. The results show that Gini index, P_0, P_1, and P_2 has a median values of 51.225, 8.155, 3.315 and 2.045 respectively. The poverty gap has a highest peak of the distribution, followed by squared poverty gap, headcount ratio, average monthly per capita income, and Gini index. The average monthly per capita survey income expenditure has an average value of 378.276 US$, having a standard deviation value of 127.690 US$ with positively skewed distribution. The mean value of children out of school, expenditures on primary education, infant mortality rate, life expectancy at birth, population growth, and expenditures on secondary education is about 6.134% of primary school age, 41.012% of education expenditures, 25.167 per 1000 live births, 71.823 years, 1.515%, and 29.610% of education expenditures.

Table 2 Panel-B shows the estimates of correlation coefficient and found that all the poverty measures including P_0, P_1, and P_2 has a positive correlation with the income inequality (i.e., $r = 0.592$, $r = 0.567$, and $r = 0.519$ respectively) while negative correlation with the per capita average monthly income ($r = -0.731$, $r = -0.633$, and $r = -0.552$ respectively). The result implies that higher economic growth lead to decrease poverty measures which confirmed the necessary condition of poverty reduction, while higher income inequality substantially increase poverty measures, which does not confirmed the sufficient condition of poverty reduction. The correlation results exhibit that the impact of higher economic growth to poverty reduction is greater than the impact of higher income inequality to increase poverty measures, which partially supported the theory of trickledown hypothesis in a panel of selected countries. The results further confirm the negative correlation between per capita income and income inequality that is the desirable condition of pro-poor growth process in a panel of selected Latin America and the Caribbean countries. The impact of children out of school, primary education expenditures, infant mortality rate, and population growth is positive on F–G–T measures of poverty indices, i.e., higher the stated non-poverty measures, higher will be the poverty incidence, while the impact of life expectancy at birth and secondary education expenditures on F–G–T measures of poverty indices is negative, which exhibit that higher the stated non-poverty measures, lesser will be the poverty incidence in a panel of countries. These results has been empirically estimated in the subsequent analysis of regression apparatus, where linear

Table 2 Descriptive statistics and correlation matrix

	P_0	P_1	P_2	Y	G	COOS	EPE	IMR	LEB	POPG	ESE
Panel-A											
Mean	9.762	4.311	2.788	378.276	51.240	6.134	41.012	25.167	71.823	1.515	29.610
Median	8.155	3.315	2.045	359.375	51.225	4.559	38.900	21.350	72.267	1.496	30.286
Maximum	50.590	24.760	15.300	720.400	63.300	34.585	67.152	85.600	80.895	3.842	45.118
Minimum	0.450	0.020	0.000	106.970	34.420	0.034	23.471	7.400	55.107	−0.064	10.105
Std. Dev.	7.353	3.824	2.761	127.690	5.134	5.704	9.983	14.114	4.352	0.631	8.132
Skewness	1.497	1.776	1.919	0.657	−0.132	1.967	0.864	1.610	−0.835	0.206	−0.465
Kurtosis	6.888	7.394	7.331	2.831	2.782	8.489	2.975	5.770	4.115	4.120	2.565
Panel-B: correlation matrix											
P_0	1.000	0.955	0.875	−0.731	0.592	0.162	0.186	0.677	−0.653	0.434	−0.277
P_1	0.955	1.000	0.978	−0.633	0.567	0.184	0.126	0.579	−0.570	0.430	−0.283
P_2	0.875	0.978	1.000	−0.552	0.519	0.190	0.071	0.483	−0.486	0.411	−0.274
Y	−0.731	−0.633	−0.552	1.000	−0.243	−0.222	−0.368	−0.533	0.586	−0.328	0.370
G	0.592	0.567	0.519	−0.243	1.000	−0.067	0.045	0.437	−0.395	0.388	−0.033
COOS	0.162	0.184	0.190	−0.222	−0.067	1.000	0.352	0.150	−0.182	0.201	−0.448
EPE	0.186	0.126	0.071	−0.368	0.045	0.352	1.000	0.208	−0.230	0.233	−0.530
IMR	0.677	0.579	0.483	−0.533	0.437	0.150	0.208	1.000	−0.926	0.353	−0.284
LEB	−0.653	−0.570	−0.486	0.586	−0.395	−0.182	−0.230	−0.926	1.000	−0.276	0.262
POPG	0.434	0.430	0.411	−0.328	0.388	0.201	0.233	0.353	−0.276	1.000	−0.321
ESE	−0.277	−0.283	−0.274	0.370	−0.033	−0.448	−0.530	−0.284	0.262	−0.321	1.000

P_0, indicates poverty headcount; P_1, indicates poverty gap; P_2, indicates squared poverty gap; 'Y', indicates income; 'G', indicates Gini coefficient; COOS, indicates children out of school; EPE, indicates expenditures on primary education; IMR, indicates infant mortality rate; LEB, indicates life expectancy at birth, POPG, indicates population growth; ESE, indicates expenditures on secondary education

and non-linear growth components included in hierarchal regression nodes to confirm the 'linear', U-shaped', and 'asymptotic' relationship between growth, inequality, and poverty in a region. Figure 2 shows the plots of differenced data of the candidate variables for ready reference.

Table 3 shows the estimates of panel random effect, panel OLS regression, and system panel GMM estimator under the absence of non-linear growth components. The results of panel random effect regression reveal that per capita income has a negative relationship with the all F–G–T measures of poverty i.e., P_0, P_1, and P_2, while income inequality has a positive relationship with all three F–G–T measures of poverty. In terms of elasticity, the results of poverty elasticity of growth and poverty elasticity of income inequality shows the more elastic relationship, as the coefficient value is greater than the value of unity. The results further imply that income inequality has a greater impact in order to increase all the three F–G–T measures of poverty as compared to the per capita income for decreasing poverty measures in a panel of selected Latin America and the Caribbean countries. The similar results has been found in panel OLS regression apparatus, where one per cent increase in the per capita income significantly decreases the headcount ratio by −1.883%, poverty gap by −1.938%, and squared poverty gap by −1.683%, while income inequality considerably increases poverty headcount by 3.911, 4.599, and 5.473% respectively. The important point is to be noted that the impact of per capita income on poverty reduction in panel OLS regression apparatus is less than the estimates of panel random effect, while the impact of income inequality on escalating poverty in panel OLS regression is far greater than the estimates of panel random effect regression. The intensity to increase income inequality in panel OLS regression estimates is obvious due to ignore the country specific and time variant shocks in a panel of selected countries. The results of system panel GMM estimator shows that average household survey income has a significant and negative relationship with the poverty headcount, i.e., if there is 1% increase in average household income, poverty declines around 0.777% points, however, the impact of income inequality

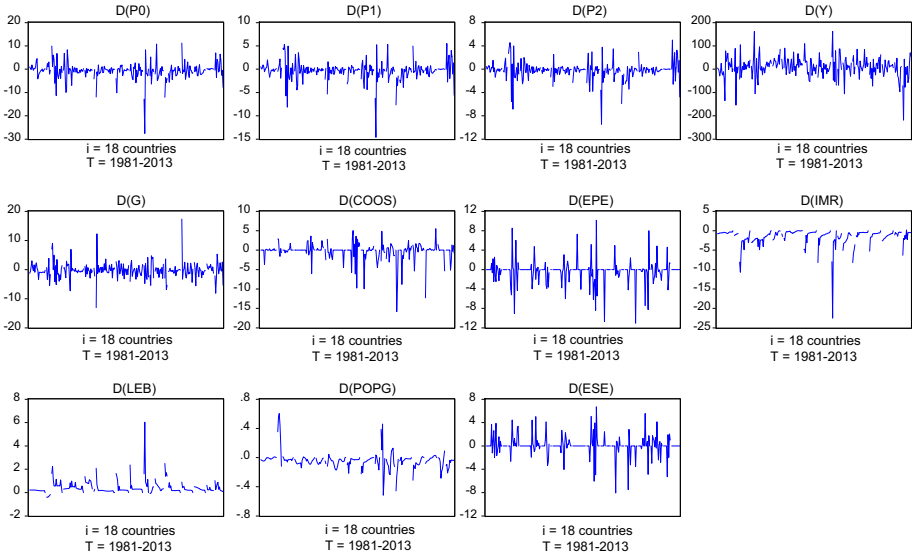

Fig. 2 Plots of differenced data. *Note*: 'D' indicates first difference. *Source*: World Bank (2015a, b)

Table 3 Results of panel random effect, Panel OLS regression, and panel GMM estimator for linear relationships between poverty, economic growth, income inequality, and non-poverty measures

Variables	Panel fixed[a]/Random effect regression			Panel OLS effect			System GMM (two step)		
	$\ln(p_0)$	$\ln(p_1)$[a]	$\ln(p_2)$[a]	$\ln(p_0)$	$\ln(p_1)$	$\ln(p_2)$	$\ln(p_0)$	$\ln(p_1)$	$\ln(p_2)$
Constant	−16.303*	−36.159*	−58.545*	−3.110	4.011	17.278**	–	–	–
$\ln(p_0)_{t-1}$	–	–	–	–	–	–	0.390*	–	–
$\ln(p_1)_{t-1}$	–	–	–	–	–	–		0.441*	–
$\ln(p_2)_{t-1}$	–	–	–	–	–	–	–	–	0.451*
$\ln(y)_t$	−2.173*	−2.785*	−1.904*	−2.009*	−2.229*	−1.890*	−0.777**	−0.678	−0.138
$\ln(g)_t$	3.562*	4.550*	5.943*	3.449*	4.068*	4.637*	0.552	0.249	0.555
$\ln(COOS)_t$	−0.008	0.042	0.113*	−0.062*	−0.079**	−0.041	−0.023	0.012	0.038
$\ln(EPE)_t$	0.273	0.696***	1.092*	−0.160	−0.211	−0.772*	1.323*	1.802**	2.338*
$\ln(ESE)_t$	0.130	0.036	0.479	0.090	0.175	−0.144	−0.145	−0.091	0.208
$\ln(IMR)_t$	0.060	−0.088	0.528**	0.019	−0.415**	−0.829*	0.423	0.248	0.508
$\ln(LEB)_t$	3.587*	7.752*	9.215*	0.837	−1.027	−4.230*	2.834	1.919	1.931
$\ln(POPG)_t$	0.133*	0.299*	0.413*	0.192*	0.365*	0.575*	0.073	0.209	0.299***
Statistical tests									
R-squared	0.862	0.844	0.902	0.876	0.723	0.709	–	–	–
Adjusted R-squared	0.858	0.827	0.891	0.872	0.714	0.700	–	–	–
F-statistics	198.440*	51.190*	86.418*	224.157*	82.722*	76.579	–	–	–
Hausman Test (Prob. value)	12.030 (0.149)	16.934 (0.030)	21.662 (0.005)	–	–	–	–	–	–
J-statistic	–	–	–	–	–	–	7.41E−26	4.72E−27	1.44E−26
Instrument rank	–	–	–	–	–	–	9	9	9
AR(1)-Prob. value	–	–	–	–	–	–	0.743	0.797	0.720
AR(2)-Prob. value	–	–	–	–	–	–	0.678	0.558	0.684

*, ** and *** indicates 1, 5 and 10% level of significance respectively. For system GMM Row (2 step) procedure, lagged dependent variable and lagged explanatory variables are used as an instrumental variables

[a] Shows panel fixed effect regression estimates

on F–G–T measures of poverty incidence is statistically insignificant during the study time period. The impact of children out of school is positive on squared poverty gap in panel fixed effect regression while it has a negative impact on poverty headcount and poverty gap in panel OLS settings. The impact of primary education, life expectancy at birth, and population growth is positive in F–G–T measures of poverty indices, while the infant mortality rate significantly influenced the squared poverty gap in a panel of selected countries. The overall results imply that the impact of economic growth and income inequality on poverty estimates confirmed the 'negative linear' relationship between them under the absence of non-linear growth components. Ravallion (2001) argued that the relationship between growth, inequality, and poverty in cross-country correlations required more in depth micro analysis to confined their impact on each other, while available evidence provoke that poors received greater benefits from rapid economic growth while received lesser benefits from economic contraction due to unjustified economic distribution. Dollar and Kraay (2002) confirmed that aggregate affluence has a considerable impact on poorest quintile for raising their average incomes that would helpful to reduce poverty across the countries. De Dominicis et al. (2008) concluded the Meta analysis for growth—inequality relationship and confirmed the differences of results due to diverse econometric applications, quality of data, and sample selection that produced controversial results between the two variables. White and Anderson (2001) argued that in majority of the cases across the world regions, growth effect dominates, while in fewer cases changes in income distribution affects poors income. The study concluded that although growth effect dominates, however, it is necessary to hold pattern of income distribution judiciously for pro-poor growth reforms across the countries. Yao (1999) discussed different findings for pro-poor growth reforms in China, while the major conclusion is that poverty incidence sensitized by growth and inequality component that hinders the flow of economic benefits towards poor peoples.

Table 4 shows the estimates of non-linear growth components in growth-inequality-poverty triangle by panel random effect, panel OLS regression and panel GMM estimator. The results of panel random effect reveal that square of per capita income considerably decreases F–G–T measures of poverty indices, while square of income inequality have a positive relationship with all the three F–G–T poverty measures. The similar results has been obtained by panel OLS regression, where square of per capita income significantly reduces poverty headcount, while income inequality increases poverty in the latter stages of economic development. The interaction term of growth and inequality are also used to assess the non-linear relationship between the variables that confirmed the negative relationship with F–G–T measures of poverty indices. The results of system panel GMM estimates show that square of per capita income significantly reduces poverty headcount and squared poverty gap, while the square of income inequality has a positive relationship with all three F–G–T measures of poverty. The overall results do not confine any reasonable U-shaped relationship among the variables. The impact of non-poverty measures including children out of school, primary and secondary education expenditures, and infant mortality rate has a positive impact on squared poverty gap in a panel random effect regression, while it further followed the positive relationships of life expectancy at birth and population growth with the F–G–T measures of poverty across nations. Janvry and Sadoulet (2000) confirmed the strong linkages between growth–inequality–poverty triangle and concluded that economic growth impacts positively on poverty reduction and negatively on increasing income inequality, however, under the premises of higher secondary school education, economic growth have a considerable greater impact on urban poverty reduction. Shahbaz (2010) concluded that economic growth has not a significant impact on

Table 4 Results of panel random effect, panel OLS regression, and panel GMM estimator for non-linear relationships between poverty, economic growth, income inequality, and non-poverty measures

Variables	Panel fixed effect[a]/random effect regression			Panel OLS effect			System GMM (two step)		
	$\ln(p_0)$	$\ln(p_1)$	$\ln(p_2)$[a]	$\ln(p_0)$	$\ln(p_1)$	$\ln(p_2)$	$\ln(p_0)$	$\ln(p_1)$	$\ln(p_2)$
Constant	−18.959*	−31.497*	−57.235*	−9.870**	−6.795	11.427	–	–	–
$\ln(p_0)_{t-1}$	–	–	–	–	–	–	−0.145	–	–
$\ln(p_1)_{t-1}$	–	–	–	–	–	–	–	−0.163**	–
$\ln(p_2)_{t-1}$	–	–	–	–	–	–	–	–	−0.153
$\ln(y\hat{}2)_t$	−0.709*	−0.512**	−1.257*	−0.440*	−0.212	−0.477	−0.821***	0.121	−1.907**
$(y \times g)_t$	−4.35E−05*	−9.63E−05*	3.74E−05	−6.42E−05*	−0.00010*				
−5.40E−05***	−1.70E−05	−0.00016**	0.0001						
$\ln(g\hat{}2)$	2.062*	2.930*	2.736*	2.183*	2.768*	2.702*	1.403*	2.305*	1.937**
$\ln(COOS)_t$	−0.009	0.023	0.115*	−0.062*	−0.079**	−0.042	−0.158	0.062	−0.187
$\ln(EPE)_t$	0.134	0.035	1.256*	−0.247**	−0.350**	−0.832*	−2.961	−4.125	−7.443
$\ln(ESE)_t$	0.095	0.153	0.518***	0.056	0.121	−0.162	2.516	2.061	4.516
$\ln(IMR)_t$	0.027	−0.273	0.583**	−0.040	−0.512*	−0.879*	−0.611	−1.618	1.368
$\ln(LEB)_t$	3.020**	4.061***	9.802*	0.456	−1.637	−4.509*	−5.735	−5.635	10.975
$\ln(POPG)_t$	0.136*	0.316*	0.407*	0.195*	0.370*	0.576*	0.307	0.640	1.010
Statistical tests									
R-squared	0.868	0.719	0.903	0.884	0.737	0.712	–	–	–
Adjusted R-squared	0.863	0.709	0.892	0.880	0.728	0.702	–	–	–
F-statistics	184.672*	71.836*	83.748*	214.179*	78.633*	68.926*	–	–	–
Hausman test (Prob. value)	9.400 (0.401)	12.320 (0.195)	22.777 (0.006)	–	–	–	–	–	–
J-statistic	–	–	–	–	–	–	3.43E−28	2.11E−28	1.34E−27
Instrument rank	–	–	–	–	–	–	10	10	10
AR(1)-prob. value	–	–	–	–	–	–	0.048**	0.192	0.573

Table 4 continued

Variables	Panel fixed effect[a]/random effect regression			Panel OLS effect			System GMM (two step)		
	$\ln(p_0)$	$\ln(p_1)$	$\ln(p_2)$[a]	$\ln(p_0)$	$\ln(p_1)$	$\ln(p_2)$	$\ln(p_0)$	$\ln(p_1)$	$\ln(p_2)$
AR(2)-prob. value	–	–	–	–	–	–	0.720	0.824	0.355

*, ** and *** indicates 1, 5, and 10% level of significance. For system GMM Row (2 step) procedure, lagged dependent variable and lagged explanatory variables are used as an instrumental variables

[a] Shows panel fixed effect regression estimates

inequality under the linear growth setting, while the study confirmed the existence of Kuznets inverted U-shaped and inverted S-shaped relationship between growth and inequality. Heshmati (2004) confirmed the global U-shaped Kuznets curve between economic growth and income inequality, while the study further confirm the negative relationship between economic growth and income inequality across the countries.

Table 5 shows the estimates of linear and non-linear growth components in a single regression apparatus and evaluated by panel random effect regression, panel OLS regression, and system panel GMM estimator. The results of panel random effect reveal that per capita income significantly reduces poverty head count and squared poverty gap, while income inequality increases poverty headcount and poverty gap. Per capita income at the later stages of development significantly reduces the poverty headcount, while interaction term decreases poverty gap in a region. In another regression apparatus, panel OLS regression reveals that per capita income decreases the poverty headcount ratio, which further prolonged to the later stages of economic development, as square of per capita income significantly reduces the poverty headcount across nations. There is a monotonic increasing relationship between income inequality and F–G–T measures of poverty indices, as income inequality increases poverty measures while the square of income inequality does not show a significant relationship with the poverty indices. The estimates of panel GMM confirm that the impact of household income expenditures and square of income on poverty headcount and poverty gap is positive, while the interaction terms of income and inequality reduces the F–G–T measures of poverty indices in a panel of countries. There is a positive impact of children out of school, primary and secondary education expenditures, and infant mortality rate on squared poverty gap, while the life expectancy and population growth significantly influenced the F–G–T measures of poverty indices. Khan et al. (2016) discussed the issues of labour market in terms of educational inequalities, health inequalities and labor force unemployment, and emphasized the need of pro-equality and pro-growth distribution for robust policy interventions to clear the market distortions across nations. Ravallion and Chen (1997) concluded that economic growth supports to reduce poverty in a good times while during recession, changes has been visible in poverty incidence due to larger income inequality. The income distribution channel should be checked and monitored during the good and bad times. Lin et al. (2009) argued that the potential factor to hinders low income countries' growth are the changes in the pattern of flow of incomes between rich and poors, while higher inequality accelerate high -income countries' growth. The policies should be formulated to sustain broad based growth for lower income countries, while policies to develop the income distribution channel in favor of poors more than non-poors for high income countries.

The other diagnostic tests for the given model confirm that the Sargan-Hansen J-statistics value is insignificant that favor the prescribed instrumental lists in the study. In addition, serial correlation tests detected by AR(1) and AR(2) confirm that the error term at the first difference are not correlated with the exogenous variables, therefore, we may safely conclude that there is no problem of serial correlation in a given model. The diagnostic tests for panel random effect and panel OLS regression indicate the goodness of fit of the model by desired range of adjusted R-squared, along with significance F-statistics, which confirm the model stability at 1% level of significance.

Table 6 shows the estimates of poverty interdependence pro-poor growth index and poverty interdependence equivalent growth rate, which combines both the linear and non-linear growth components in an existing pro-poor growth index. This index would be better and comprehend from previous available pro-poor growth indices as its included non-linear growth components to overcome the problem of non-linearity in pro-poor growth process.

Table 5 Results of panel random effect, Panel OLS regression, and panel GMM estimator for linear and non-linear relationships between poverty, economic growth, income inequality, and non-poverty measures

Variables	Panel fixed effect[a]/random effect regression			Panel OLS effect			System GMM (two step)		
	$\ln(p_0)$	$\ln(p_1)$	$\ln(p_2)$[a]	$\ln(p_0)$	$\ln(p_1)$	$\ln(p_2)$	$\ln(p_0)$	$\ln(p_1)$	$\ln(p_2)$
Constant	−8.450	−30.713**	−44.298*	−3.962	−7.446	10.471	–	–	–
$\ln(p_0)_{t-1}$	–	–	–	–	–	–	0.474*	–	–
$\ln(p_1)_{t-1}$	–	–	–	–	–	–	–	0.345*	–
$\ln(p_2)_{t-1}$	–	–	–	–	–	–	–	–	0.361*
$\ln(y)_t$	−1.979*	−0.759	−2.736*	−1.423*	−0.129	−0.914	6.731*	7.275***	7.459
$\ln(g)_t$	2.953**	4.484***	2.916	4.001*	5.021***	5.575***	−4.680	−19.389	−29.829
$(y\text{^}2)_t$	−3.41E−06*	1.41E−06	1.79E−06	−2.81E−06*	1.29E−06	2.43E−07	6.59E−06*	9.76E−06***	9.21E−06
$(y \times g)_t$	4.31E−05	−0.00013*	8.05E−05	1.38E−05	−0.00014*	−6.04E−05	−0.00052*	−0.00060**	−0.00057***
$(g\text{^}2)_t$	−4.61E−05	0.0004	0.0003	−0.0002	0.0002	−1.07E−05	0.002	0.006	0.008
$\ln(COOS)_t$	−0.010	0.026	0.114*	−0.066*	−0.078**	−0.042	−0.063**	−0.039	−0.007
$\ln(EPE)_t$	−0.009	0.122	1.139*	−0.253*	−0.345***	−0.831*	−0.343*	0.823	1.532
$\ln(ESE)_t$	0.100	0.120	0.535***	0.048	0.112	−0.158	−0.248	−0.621	−0.443
$\ln(IMR)_t$	−0.022	−0.274	0.515**	−0.034	−0.521*	−0.879*	−0.291	−0.478	−0.453
$\ln(LEB)_t$	2.331***	4.590**	9.193*	0.054	−1.436	−4.476*	−0.793	0.666	0.975
$\ln(POPG)_t$	0.180*	0.295*	0.435*	0.187*	0.372*	0.577*	0.133*	0.283	0.453
Statistical tests									
R-squared	0.875	0.720	0.904	0.888	0.738	0.712	–	–	–
Adjusted R-squared	0.870	0.708	0.892	0.883	0.726	0.700	–	–	–
F-statistics	160.360*	58.625*	78.069*	181.762*	64.074*	55.949*	–	–	–
Hausman test (Prob. value)	7.191 (0.783)	11.324 (0.416)	18.563 (0.069)	–	–	–	–	–	–
J-statistic	–	–	–	–	–	–	8.79E−23	3.31E−23	1.68E−22
Instrument Rank	–	–	–	–	–	–	12	12	12
AR(1)-Prob. value	–	–	–	–	–	–	0.368	0.737	0.564

Table 5 continued

Variables	Panel fixed effect[a]/random effect regression			Panel OLS effect			System GMM (two step)		
	$\ln(p_0)$	$\ln(p_1)$	$\ln(p_2)$[a]	$\ln(p_0)$	$\ln(p_1)$	$\ln(p_2)$	$\ln(p_0)$	$\ln(p_1)$	$\ln(p_2)$
AR(2)-Prob. value	–	–	–	–	–	–	0.566	0.640	0.595

*, ** and *** indicates 1, 5, and 10% level of significance respectively. For system GMM Row (2 step) procedure, lagged dependent variable and lagged explanatory variables are used as an instrumental variables

[a] Shows panel fixed effect regression estimates

Table 6 Estimates of poverty interdependence growth index and poverty interdependence equivalent growth index

Countries	Years	AGR	Poverty headcount (p_0)					Poverty gap (p_1)				
			η	ζ	δ	φ	γ	η	ζ	δ	φ	γ
Argentina-Urban	1991 and 2013	15.303	−9.658	8.008	−1.65	0.170	2.614	−8.66	7.944	−0.716	0.082	1.265
Belize	1993 and 1999	−21.260	−1.497	−2.955	−4.452	2.973	−63.228	−1.594	−1.453	−3.047	1.911	−40.641
Bolivia	1990 and 2013	82.284	−2.169	5.025	2.856	−1.316	−108.347	−0.136	9.145	9.009	−66.242	−5450.73
Brazil	1981 and 2013	80.888	−4.461	9.498	5.037	−1.129	−91.333	−3.939	7.705	3.766	−0.956	−77.336
Chile	1987 and 2013	96.552	−7.881	19.314	11.433	−1.450	−140.069	−7.881	19.314	11.433	−1.450	−140.069
Columbia-Urban	1988 and 1991	0.950	−6.032	2.054	−3.978	0.659	0.626	−8.779	0.38	−8.399	0.956	0.909
Costa Rica	1981 and 2013	15.126	−4.105	−7.921	−12.026	2.929	44.313	−4.249	−7.554	−11.803	2.777	42.017
Dominican Republic	1986 and 2013	8.048	−5.1	7.207	2.107	−0.413	−3.325	−5.37	8.796	3.426	−0.637	−5.135
El Salvador	1991 and 2013	38.248	−4.698	9.646	4.948	−1.053	−40.284	−5.816	15.194	9.378	−1.612	−61.673
Guatemala	1986 and 2011	309.976	−3.526	10.703	7.177	−2.035	−630.941	−4.194	13.747	9.553	−2.277	−706.056
Jamaica	1988 and 2004	96.647	−4.255	−8.417	−12.672	2.978	287.831	−4.218	−8.221	−12.439	2.949	285.017
Mexico	1989-2012	43.960	−6.357	7.678	1.321	−0.207	−9.135	−6.989	6.827	−0.162	0.023	1.018
Nicaragua	1993 and 2009	93.799	−3.957	5.017	1.06	−0.267	−25.126	−5.322	6.859	1.537	−0.288	−27.089
Panama	1989 and 2013	129.466	−7.799	15.967	8.168	−1.047	−135.592	−11.193	24.211	13.018	−1.163	−150.575
Paraguay	1989 and 2013	696.148	−4.354	10.859	6.505	−1.494	−1040.07	−3.703	13.381	9.678	−2.613	−1819.42
Peru	1997 and 2013	80.681	−7.962	7.089	−0.873	0.109	8.846	−9.931	9.178	−0.753	0.075	6.117
Uruguay	1992 and 2005	−346.081	−5.649	7.039	1.39	−0.246	85.1571	−3.315	2.905	−0.41	0.123	−42.803
Venezuela	1981 and 2006	−292.263	−7.082	−8.68	−15.762	2.225	−650.472	−14.062	−26.38	−40.442	2.875	−840.541

Countries	Years	AGR	Squared poverty gap (p_2)				
			η	ζ	δ	φ	γ
Argentina-Urban	1991 and 2013	15.303	−7.642	7.62	−0.022	0.002	0.044
Belize	1993 and 1999	−21.260	−2.078	−0.434	−2.512	1.208	−25.701
Bolivia	1990 and 2013	82.284	1.52	12.655	14.175	9.325	767.354

Table 6 continued

Countries	Years	AGR	Squared poverty gap (p_2)				
			η	ζ	δ	φ	γ
Brazil	1981 and 2013	80.888	−3.323	6.218	2.895	−0.871	−70.470
Chile	1987 and 2013	96.552	−5.913	15.166	9.253	−1.56486	−151.091
Columbia-Urban	1988 and 1991	0.950	−10.984	−1.238	−12.222	1.112	1.057
Costa Rica	1981 and 2013	15.126	−4.19	−6.905	−11.095	2.6479	40.053
Dominican Republic	1986 and 2013	8.048	−5.146	10.078	4.932	−0.958	−7.714
El Salvador	1991 and 2013	38.248	−6.797	19.736	12.939	−1.903	−72.811
Guatemala	1986 and 2011	309.976	−4.485	14.88	10.395	−2.317	−718.439
Jamaica	1988 and 2004	96.647	−4.531	−8.59	−13.121	2.895	279.875
Mexico	1989–2012	43.960	−6.986	5.502	−1.484	0.212	9.338
Nicaragua	1993 and 2009	93.799	−6.221	8.523	2.302	−0.370	−34.709
Panama	1989 and 2013	129.466	−13.805	30.56	16.755	−1.213	−157.132
Paraguay	1989 and 2013	696.148	−2.993	14.062	11.069	−3.698	−2574.56
Peru	1997 and 2013	80.681	−11.43	10.704	−0.726	0.063	5.124
Uruguay	1992 and 2005	−346.081	−0.809	−0.103	−0.912	1.127	−390.143
Venezuela	1981 and 2006	−292.263	−4.273	8.577	4.304	−1.007	−294.383

AGR indicates annual growth rate of mean dollar income between two household surveys. η, indicates poverty elasticity of growth; ζ, indicates poverty elasticity of inequality; δ, indicates total poverty elasticity; φ, indicates poverty intensive growth index; γ, indicates poverty intensive equivalent growth index; 'p_1', indicates poverty gap; 'p_2', indicates squared poverty gap

The results show that Argentina-Urban (Household survey data i.e., 1991 and 2013) is intrinsically not considered as a pro-poor, although the country has a greater share of poverty elasticity of growth as compared to the poverty elasticity of inequality, however, the lower value of poverty intensive pro-poor growth index may not pronounce pro-poor growth and poors not marginally benefited from existing growth reforms in a country. Belize (1993 and 1999) although has a negative annual growth rate of −21.260, however, this negative growth rate subsequently reduces income inequality that favor the poors. The value of poverty intensive pro-poor growth index surpasses the threshold value of unity, which indicates that the growth process was highly pro-poor and poors' received marginal benefits as compared to the non-poors in a country. The case study of Bolivia (1990 and 2013) is very interesting, as on one side, under the presence of poverty gap and squared poverty gap, the larger share value of inequality and lower share value of economic growth tends to become 'immiserize' the growth index, as the index value becomes negative, while in case of severity of poverty, the positive and lower value of growth elasticity of poverty, and positive and larger value of inequality elasticity of poverty surpasses the index value is greater than unity, which exhibit that poors whom have a distance far from the poverty line received marginal benefits as compared to the ultra poors and non-poors in a country. The Columbia-urban (1988 and 1991), Costa Rica (1981 and 2013), and Jamaica (1988 and 2004) are highly pro-poor countries, as the index value is greater than unity, and poors received marginal gains from the existing growth reforms that were held in a particular countries. Venezuela (1981 and 2006) shows highly pro-poor growth index in case of poverty head count and poverty gap, while the index value becomes less than the threshold value of unity in case of squared poverty gap. One of the major reason for anti-poor growth in case of severity of poverty is that the elasticity value of income inequality is almost double than the elasticity value of per capita income that 'immiserize' the growth index becomes negative. The remaining countries such as, Brazil (1981 and 2013), Chile (1987 and 2013), Dominican Republic (1986 and 2013), El Salvador (1991 and 2013), Guatemala (1986 and 2011), Mexico (1989 and 2012), Nicaragua (1993 and 2009), Panama (1989 and 2013), Paraguay (1989 and 2013), and Uruguay (1992 and 2005), all countries shows that the growth index is negative, which Bhagwati (1988) calls the 'immiserizing' growth phase. This growth phase is attributed because of two main reasons, at first, high per capita income considerably increase F–G–T measures of poverty (rather than reducing poverty), and secondly, the share of income inequality relative to increasing poverty is far greater than the beneficial impact of per capita growth, which offsets the growth effects relative to the rising inequality in a country profiles.

The overall results of poverty interdependence pro-poor growth index comparatively more robust and pragmatic in a sense that it has included not only linear components of growth, while it has included non-linear growth components, which previously largely ignored while making pro-poor growth indices. The gains and/or losses of growth are further assessed by the poverty interdependence equivalent growth rate, which merely satisfied the monotonicity criterion of pro-poor growth and poverty reduction. Both the indices fairly accompanied with the linear and non-linear growth components that previously crowded by the linearity proposition of pro-poor growth rates. The study provoke that this new measure of pro-poor growth index provide better survey results as compared to the available pro-poor growth indices in development literature.

4 Conclusions

The objective of the study is to examine the linear and non-linear relationships between growth, inequality, poverty, and non-poverty measures in a panel of 18 selected Latin America and the Caribbean countries by utilizing the different household available surveys for the periods of 1981–2012. The study proposed a new measure of pro-poor growth index, called poverty interdependence growth index (PIGI), which are based on non-linear symmetric poverty decomposition that evaluates the pro-poor growth reforms in the later stages of economic development. This index further satisfied the monotonicity criterion of pro-poor growth and poverty reduction, called 'poverty interdependence equivalent growth index (PIEGI)' that evaluates the gains and/or losses of growth. The following key results has been drawn by this exercise i.e.,

1. Panel correlation results confirm the 'negative linear' relationships between the growth, inequality and poverty under the absence of non-linear growth components, while this result further confirmed through panel fixed effect, panel least square regression, and system panel GMM estimates.
2. While including both linear and non-linear growth components in growth-inequality-poverty triangle, the study was not confined any reasonable form of relationships either 'U-shaped' or 'asymptotic' relationship between the variables.
3. The population growth, education, and health expenditures increase the F–G–T measures of poverty indices across nations.
4. The study proposed a new form of pro-poor growth index, which includes both linear and non-linear growth components in order to absorb the later stages of economic development that were merely ignored in the available pro-poor growth indices.
5. This index, we called 'poverty interdependence pro-poor growth index' that falls in the strict definition of pro-poor growth under relative approach, which merely based on poverty line and poverty measures.
6. This index further extended to capture the gains and/or losses of growth that satisfied both necessary and sufficient condition of poverty reduction. We judged this index by the product (multiplication) of poverty interdependence pro-poor growth index and the actual growth rate of survey income between two time periods, called poverty interdependence pro-poor growth rate.
7. The results of proposed pro-poor growth indices show that out of 18 selected Latin America and the Caribbean countries, only 4 countries show the highly pro-poor growth, which confirm that the growth process facilitate the poors as compared to the non-poors. We classified this situation as 'trickle down', where lower income strata group get benefited from the existing growth reforms held in a countries.
8. Further, there are 11 countries that have a negative index value, which are merely two main reasons i.e., firstly, the higher economic growth increases poverty, secondly, the share of income inequality into increasing poverty is far greater than the impact of economic growth on poverty, which we referred this situation as 'immiserizing' growth phenomenon in particular countries.
9. Finally, there are three countries that shows anti-poor growth, where growth process benefited the non-poors as compared to the poors in their countries.

The study concludes that economic growth does not necessarily translate the poverty reduction; if and only if, there should be judicious income distribution channels that facilitate and expedite the process of pro-poor growth reforms across the countries. The

policies should be formulated in order to sustained broad-based growth along with rational income distribution channel that would get marginally benefited the poors as compared with the non-poors. For broad-based growth, it is necessary to include social expenditures in pro-poor growth agenda, which would facilitate the poors to escape out from poverty; while for rational income distribution, the policy makers and government officials required a comprehend taxation policies that should be flexible and elastic, and fulfill the basis of pro-equality growth notions.

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