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Progress in child stunting across the world from 1990 to 2015: testing the global convergence hypothesis

Shalem Balla[1], Srinivas Goli[2,3,*], Srilakshmi Vedantam[1] and Anu Rammohan[4]
[1]International Institute for Population Sciences, Mumbai, India: [2]Australia India Institute New Generation Network Scholar, The University of Western Australia (M251), Crawley, WA, Australia: [3]Population Studies, Centre for the Study of Regional Development (CSRD), Jawaharlal Nehru University, New Delhi, India: [4]Department of Economics, UWA Business School, The University of Western Australia (M251), Crawley, WA, Australia

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Abstract

Objective: This study has two-fold objectives: first, to test the global convergence hypothesis in the progress of child stunting across 174 countries over the period 1990–2015; second, to identify factors determining the process of convergence or divergence.
Design: The study design comprises macro-level cross-country analyses. Our empirical strategy uses parametric convergence models such as absolute and conditional β-convergence models, while non-parametric convergence models such as Kernel density plots serve as robustness checks.
Setting: The study uses a global setting comprising child stunting information from 174 countries.
Participants: The participants for this study are 174 countries. The information on child stunting prevalence for most countries is available from the UNICEF-WHO-WB Joint Child Malnutrition Estimates Expanded Database (April-2019), while national-level surveys are used for those countries where UNICEF-WHO-WB Database is not available. The data for socio-economic variables are taken from the World Bank's data bank (1990–2015).
Results: Findings from the absolute β-convergence model estimates show that progress in child stunting has diverged over the entire period (1990–2015). However, the speed of divergence has reduced for the recent period (2010–2015). The conditional β-convergence model estimates show that cross-country heterogeneity in GDP per capita, poverty and health care expenditure are significant factors explaining divergence in child stunting.
Conclusions: For replacing current divergence with convergence in child stunting worldwide, the study demonstrates the critical role of economic factors and public spending on health care to reduce child stunting, particularly in countries where progress is slow.

Keywords
Child stunting
Convergence
Divergence
Absolute inequality
Relative inequality
World countries

Globally there has been a decrease in childhood stunting over the last three decades, with the proportion of stunted pre-school age children declining from nearly 40 % in 1990 to 23 % in 2015[1]. However, regional and between-country inequalities in childhood nutrition measures are widely observed. For instance, stunting prevalence since 2000 has declined by two-thirds in upper-middle-income countries, while high levels of stunting are still observed in low and lower-middle-income countries. The countries in Africa and Asia bear the largest burden of childhood malnutrition. Notably, the number of stunted children increased in Africa from 50·3 to 58·8 million between 2000 and 2018. Similarly, 55 % of stunted children below 5 years live in Asia[2].

Previous research has examined the determinants of stunting in low-income countries, which is attributed to socio-economic factors such as poverty, inequality, insufficient and incorrect feeding practices, poor dietary diversity, and poor maternal and child health care[3–10]. Furthermore, much of the previous literature on child

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nutritional inequalities has focused on the most recently available information. However, estimates based on recent nutrition data have serious limitations in terms of understanding the true trajectories of between-country inequalities[11].

The international community is paying increasing attention to novel measures of monitoring global health indicators towards the targets of Sustainable Development Goals (SDG). While SDG are an internationally accepted development agenda, the most crucial target of achieving a key goal like SDG-2 (zero hunger and proper nutrition to all) also needs robust quantitative evidence on measuring and monitoring the progress towards the elimination of childhood undernutrition. Moreover, the important tasks of global nutrition policy are not limited to improving average child nutrition, but rather there is an imperative need for greater focus in reducing regional and inter-country inequalities in child nutrition. The dissimilar rates of progress in childhood nutritional status across different countries make it difficult to achieve SDG-2[2].

The heterogeneity in global progress in child stunting provides an ideal setting to test the 'Global Convergence Hypothesis' in child stunting. The aim of this study is to empirically analyse if global progress in child stunting (measured using 'height-for-age' of children under 5 years) is converging or diverging? To the best of our knowledge, our paper is the first to test the 'Global Convergence Hypothesis' in the rate of progress towards the reduction of stunting in children aged 0–59 months across 174 countries during 1990–2015. Our study makes a timely attempt to fill these gaps in knowledge on global child nutrition.

Our specific objective are: first, to systematically map the regional and country-level trajectories of progress achieved in the process of elimination of child stunting, where growth trajectories remain hidden. Second, to quantify the convergence or divergence in the progress of child stunting using robust quantitative techniques. Finally, we identify the reasons behind converging or diverging progress in 'height-for-age' among children aged below 5 years.

We used standard convergence metrics such as absolute and conditional β-convergence models for testing the convergence hypothesis in global progress of height-for-age among children aged under-five years over the period 1990–2015. Our findings show divergence in global progress towards reducing stunting. The evidence from the study about reasons behind the divergence in child stunting will help policy makers around the world in prioritising the post-2020 development agenda for achieving a 'Grand Global Convergence' childhood nutritional status. Moreover, testing the convergence hypothesis is a handy and effective tool for measuring and monitoring global progress in childhood nutrition status.

Methods

Data

Our analyses used data from multiple data sources. The information on stunting prevalence for most countries is available from the UNICEF-WHO-WB Joint Child Malnutrition Estimates Expanded Database (April 2019), while national-level surveys are used for those countries where Joint Child Malnutrition Estimates Expanded Database is not available. We have compiled child stunting data for over 180 countries (ranging from 183 countries in 1990–1995 to 187 countries in 2010–2015). The final sample includes data for 174 countries for whom data were available for all our variables of interest across time. The data for socio-economic variables are taken from the World Bank's data bank (1990–2015). Although the information on some socio-economic variables is missing for a few countries, the final sample size is robust enough for testing the 'Global Conditional Convergence Hypothesis' in the progress of 'height-for-age' among children. Below, we have described our study variables in detail.

Outcome variable

The primary outcome variable for the empirical analyses is a measure of child stunting, which is derived from a child's height-for-age, a measure of linear growth. It is expressed as *Z*-scores in SD from the reference population's mean, calculated using 2006 WHO Child Growth Standards reference population median and SD[12].

Among children aged 0–60 months, stunting is defined as having a height-for-age *Z*-score below –2 SD (moderate stunting) and –3 SD (severe stunting) from the median of the WHO Child Growth Standards. In this study, we considered moderate stunting estimates.

Predictor variables

The predictor variables used in this study include an array of socio-economic and demographic variables, such as the proportion of the population with access to basic sanitation, drinking water, female literacy rate, GDP per capita, percentage share of health expenditure in GDP, Gini index (as a measure of inequality), poverty headcount ratio and air pollution. The final sample includes panel data for two time points and 174 cross-sections (countries) for the selected indicators. Table 1 presents the data source and descriptive statistics for the variables used in the empirical analyses, while online supplementary material, Supplemental Appendix 1 provides the definitions of study variables.

The descriptive statistics in Table 1 show that the mean prevalence of stunting has declined from 26 % in 1990–2005 to 18 % in 2010–2015. However, it varies from just 1·3 % in Germany to 57·6 % in Burundi in 2010–2015. Although the socio-economic conditions in individual countries are different from two decades ago, there are

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Table 1 Summary statistics of child stunting and its correlates across the world countries, 1990–1995 to 2010–2015

Variable	Observations	Mean	SD	Min	Max	Data source
Prevalence of stunting in children (%) in 1990–1995	183	26·47	18·29	2·00	68·47	UNICEF-WHO-WB Joint Child Malnutrition Estimates Expanded Database[25]
Prevalence of stunting in children (%) in 2000–2005	186	22·61	16·30	1·90	60·83	
Prevalence of stunting in children (%) in 2010–2015	187	18·32	13·99	1·30	57·60	
People using basic sanitation facilities (%) in 1990–1995	189	65·70	32·40	3·50	100	World Bank (1990–2015)[26]
People using basic sanitation facilities (%) in 2000–2005	190	68·66	31·43	3·80	100	
People using basic sanitation facilities (%) in 2010–2015	194	72·79	29·57	6·40	100	
People using basic drinking water (%) in 1990–1995	193	79·16	21·56	15·48	100	World Bank (1990–2015)[27]
People using basic drinking water (%) in 2000–2005	190	81·28	20·90	17·09	100	
People using basic drinking water (%) in 2010–2015	192	85·29	18·18	18·67	100	
Poverty head count ratio (%) in 1990–1995	147	26·61	27·60	0·00	95	World Bank (1990–2015)[28]
Poverty head count ratio (%) in 2000–2005	146	21·28	23·16	0·00	94	
Poverty head count ratio (%) in 2010–2015	150	14·30	19·86	0·00	78·05	
Female literacy rate age (15+) (%) in 1990–1995	152	70·42	28·37	1·90	100	World Bank (1990–2015)[29]
Female literacy rate age (15+) (%) in 2000–2005	154	75·40	25·23	12·24	100	
Female literacy rate age (15+) (%) in 2010–2015	159	78·70	24·70	13·93	100	
GDP per capita (US$) in 1990–1995	170	8872·86	12 975·85	170·69	76 492·39	World Bank (1990–2015)[30]
GDP per capita (US$) in 2000–2005	177	10 154·59	14 600·73	207·97	85 113·99	
GDP per capita (US$) in 2010–2015	179	11 749·53	15 779·78	235·92	91 942·29	
PM2·5 air pollution (mg/m^3) in 1990–1995	181	29·94	17·24	6·79	90·81	World Bank (1990–2015)[31]
PM2·5 air pollution (mg/m^3) in 2000–2005	181	29·46	16·84	7·06	91·08	
PM2·5 air pollution (mg/m^3) in 2010–2015	181	28·76	17·31	6·65	98·03	
GINI index (for economic inequality) in 1990–1995	158	41·06	9·98	22·56	65·80	World Bank (1990–2015)[32]
GINI index (for economic inequality) in 2000–2005	154	39·42	8·83	24·70	64·70	
GINI index (for economic inequality) in 2010–2015	159	37·63	8·28	23·70	68·70	
Total population in 1990–1995 (in thousands)	196	28 000	110 000	9156	1 180 000	World Bank (1990–2015)[33]
Total population in 2000–2005 (in thousands)	196	32 100	125 000	9767	1 290 000	
Total population in 2010–2015 (in thousands)	196	36 200	137 000	10 819	1 360 000	
GDP in health expenditure (%) in 1990–1995	178	5·78	3·031 177	1·57	25·15 146	World Bank (1990–2015)[34]
GDP in health expenditure (%) in 2000–2005	181	6·04	2·659 387	1·84	21·49 388	
GDP in health expenditure (%) in 2010–2015	182	6·50	2·782 929	1·76	19·65 573	

large inter-country differences in socio-economic characteristics. For instance, the GDP per capita varies from \$236 in Burundi to \$91 942 in Luxembourg. Similarly, female literacy rates vary from 13·9 % in Chad to 100 % in the Democratic People's Republic of Korea and Norway. Income inequality measured by the Gini index varies from 24 in Kazakhstan to 69 in Albania, and the proportion of GDP spent on health varies from 1·7 % in Equatorial Guinea to 19·6 % in the Marshall Islands. The share of households having access to basic sanitation facilities ranges from 6·4 % in Ethiopia to 100 % in Japan, New Zealand, Kuwait, Republic of Korea, Singapore and the USA. The poverty headcount ratio varies from 0 % in Bhutan, Cuba, France and Germany to 78·05 % in the Maldives. The share of population with access to basic drinking water also differs from 18·7 % in Eswatini to 100 % in Andorra, Austria, Belgium, Cyprus, Denmark, Finland and Greenland.

Patient and public involvement

The present study does not involve patient and member of the public in the design, or conduct, or reporting, or dissemination plans of the research. The research completely based on above-stated secondary sources of information available in public domain for open access.

Empirical strategy

Our empirical strategy includes a three-stage analytical methodology. First, we use catching-up plots to detect whether laggard countries in terms of child 'height-for-age' are catching-up with their advanced counterparts. In the second stage, the absolute β-convergence (or a Barro-regression) model is used to determine whether progress in child stunting is converging or diverging across countries during the period 1990–2015. In the last stage, a conditional Barro-regression model is used to determine the factors contributing to converging or diverging progress in child stunting. Additionally, some robustness checks for our base convergence estimates are performed using Kernel density plots and inter-country absolute and relative inequality measures.

Catching-up process

The catching-up process defines the progress made by laggard countries to catch-up with their advanced counterparts in an ideal set-up. The identification of the catching-up process is a necessary precondition to test a convergence hypothesis. It can be identified using catching-up plots. In our analyses, a catching-up plot displays the correlation between 'changes in child stunting (from 1990 to 2015)' and 'stunting prevalence in the base year' across countries.

Absolute β-convergence model

The absolute β-convergence model is used when the space between the laggard and developed countries shrink, precisely due to more significant improvement in laggard countries. The β-convergence model for a cross-section of countries assumes an inverse relationship between an indicator's initial levels and its growth rate[13–15]. The mathematical expression of the model for estimation of β-convergence is:

$$\ln\left[Y_{i,t+k}Y_{i,t}\right] = \propto + \beta.\ln\left(x_{i,t}\right) + \varepsilon_{i,t} \quad (1)$$

where the term $\ln\left[x_{i,t+k}x_{i,t}\right]$ is the average annual rate of decline in stunting in a country i for the period $(t, t+k)$; and $x_{i,t}$ is the value in the period 1990–1995, and the term $\varepsilon_{i,t}$ refers to the corresponding residuals. The convergence speed is computed as s = −ln [(1 + β)/T] where s is the convergence speed, β is the β-convergence and T refers to the time[14,16–18].

Conditional convergence model

The conditional β-convergence model is used to account for the variability of explanatory indicators in the formal β-regression model[14,17]. Conditional Barro-regression will help us identify the factors responsible for divergence in stunting. Alternatively, it allows us to focus on factors that would create convergence in global stunting[11]. The mathematical expression for this model is:

$$\ln\left[Y_{i,t+k}Y_{i,t}\right] = \propto + \beta.\ln\left(x_{1,i.t}x_{2,i.t}x_{3,i.t.....}x_{n,i.t}\right) + \varepsilon_{it} \quad (2)$$

where $\ln\left[Y_{i,t+k}Y_{i,t}\right]$ is the average annual rate of decline in stunting in a country i for the period $(t, t+k)$, and $x_{i,t}$ is the value in the period 1990–1995, and $\varepsilon_{i,t}$ refers to the corresponding residuals. The term x_1 is the initial value of child stunting, x_2 is the log of poverty, x_3 is the log of Gini index, x_4 is the log of GDP per capita in US\$, x_5 is the log of female education, x_6 is the log of percentage of GDP in health expenditure, x_7 is the log of basic sanitation facilities, x_8 is the log of drinking water and x_9 is the log of air pollution in time $(t, t+k)$.

Kernel density plot

Kernel density estimates are a widely used non-parametric method to assess convergence metrics, using Kernel smoothening to plot the values. The peaks help in identifying the concentration of values over the intervals. The distribution fitted by the Kernel density function using exploratory data analysis depends on the observed distribution based on available data values. Unlike parametric distribution, the non-parametric distribution uses kernel density functions to estimate the underlying distribution's unknown scale and locational parameter. The mathematical expression of the model is widely reported elsewhere, see[11,20,21].

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Absolute inequality

Although a few prior studies have focused on global disparity in gender inequality, income inequality and health inequality[22–24], there is limited research in measuring absolute and relative inequality in child stunting. The average inter-country disparity (AID) measures the degree of dispersion that exists at any point of time in stunting. It calculates the average absolute inter-country difference in stunting, weighted by the under-five population size of the countries. Moreover, changes in the AID indicate whether child stunting decreases (convergence) or increasing (divergence) across the globe. The mathematical expression used for calculating AID is:

$$AID = \frac{1}{2(l_0)^2}\sum_x \sum_y S_x * S_y \left| W_x - W_y \right| \qquad (3)$$

where x, y are the countries, S is the prevalence rate of child stunting and W is the weight of the country and $\sum_x W_x = \sum_y W_y = l_0$.

Relative inequality

The Gini index measures the relative inequality in child stunting. Coefficient *0* represents perfect equality, whereas *1* represents perfect inequality. The mathematical expression used for calculating the Gini index is:

$$G = \frac{AID}{\grave{u}} \qquad (4)$$

AID is the average inter-country disparity, and $\grave{u}$ is the product of the prevalence rate of stunting and under-five child population weight.

Results

Trends and changes in child stunting

The trends in global child stunting are shown in Fig. 1 according to the developmental regions based on World Bank income grouping. Globally, child stunting has declined from 34·1 % in 1990–1995 to 21·2 % in 2010–2015. The decline is also observed across all the developmental regions of the world, but the volume of decline varies considerably across them. For instance, in both low-income and lower-middle-income countries, child stunting has declined from 52·1 % in 1990–1995 to 38·2 and 35 %, respectively, in 2000–2005 and 2010–2015. In these regions, the pace of decline has slowed down between 2000–2005 and 2010–2015. We observe just 3 % change during 2000–2005 to 2010–2015 compared with a 14 % change in the previous decade, 1990–1995 to 2000–2005. The highest amount of decrease has been observed in the upper-middle-income countries, where stunting has declined from 27·9 % in 1990–1995 to 8·7 % in 2010–2015, a nearly three and half times drop from initial levels. However, there is very little change among countries in the high-income category which already had low levels of stunting (3·9 % in 1990–1995 and 2·7 % in 2010–2015).

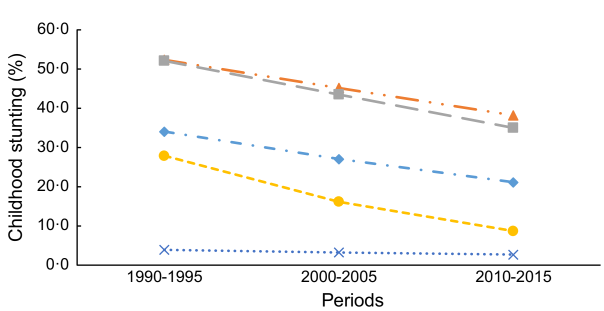


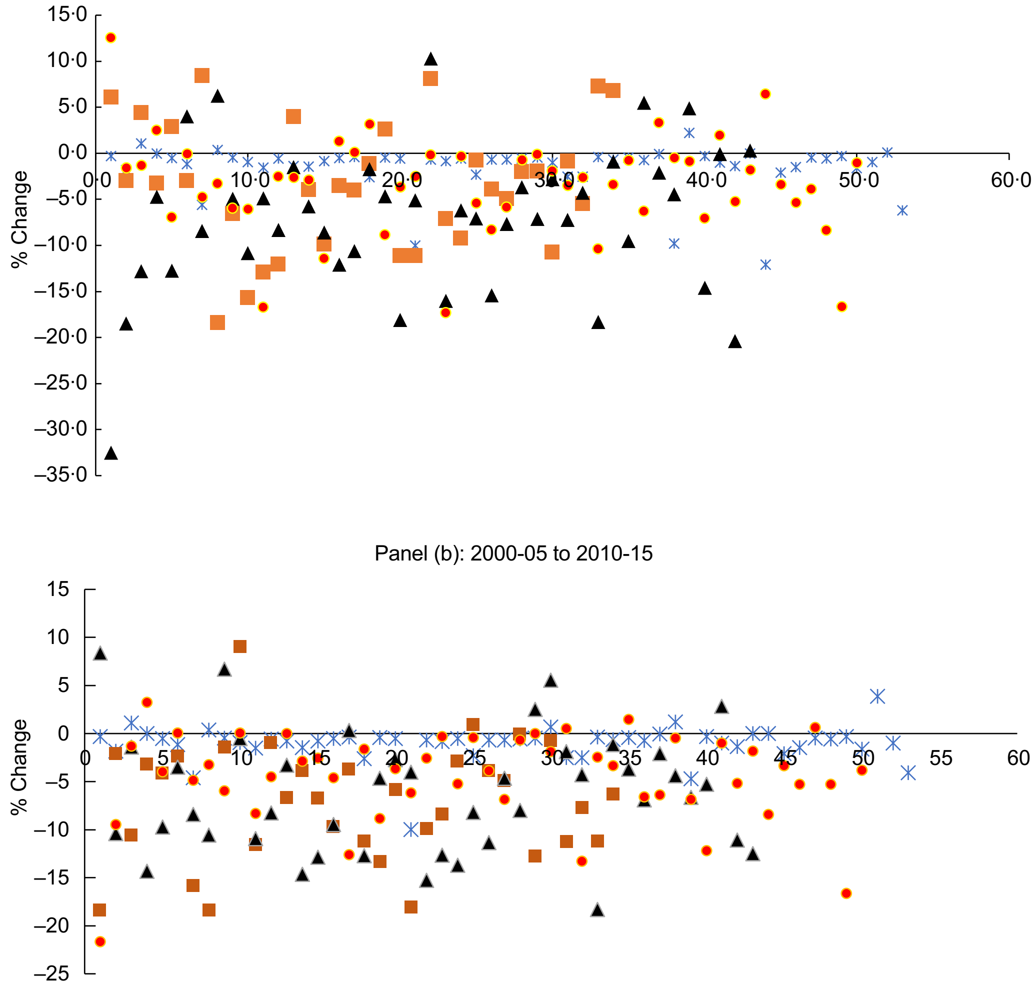
Fig. 1 (colour online) Global and regional trends in childhood stunting from 1990–1995 to 2010–2015. ··×··, high income; ··×··, lower income; –▲·, lower-middle income; –■·, upper-middle income; –●–, world

Further, in Fig. 2(a) and (b), we have examined trends in absolute change in child stunting for individual countries for the periods 1990–1995 to 2000–2005 and 2000–2005 to 2010–2015. The results in Fig. 2(a) show that except for fourteen countries, stunting prevalence has decreased worldwide between the period 1990–1995 and 2000–2005. These fourteen countries include low-income countries such as Afghanistan, Comoros, Yemen, Zimbabwe, Cote D'Ivoire, Lesotho, Palestine and lower-middle-income countries such as Tunisia and Argentina. However, there has also been an increase in child stunting prevalence among upper-middle-income countries such as Albania, Armenia, Fiji, North Macedonia, and also in Panama, a high-income country.

For the recent period, 2000–2005 to 2010–2015, the results from Fig. 2(b) suggest that although the number of countries with poor or negative progress has dropped compared with the initial period, 1990–1995 to 2000–2005, there are large disparities in the rate of change across the countries from all developing regions. This unequal rate of progress provides an ideal setting for testing the hypotheses of the catching-up process and convergence. In the following sections, we discuss the results from testing the catching-up process and global convergence hypothesis in child stunting.

Catching-up process

Figure 3 shows a scatterplot of changes in child stunting in 174 countries from 1990–1995 to 2010–2015 over the prevalence of child stunting in the base year (1990–1995). For the convergence process to occur, the laggard countries should experience greater positive change in child stunting relative to countries with lower prevalence rate in the initial period. Our results show a negative association between the level of changes in child stunting during 1990–1995 to 2010–2015 relative to the initial period (1990–1995), indicating a lack of progress towards convergence in child stunting.



Note: Every single point represents a country

Fig. 2 (colour online) Absolute change in childhood stunting across the world countries during 1990–2015. ✳, high income; ■, low income; ▲, lower-middle income; ●, upper-middle income

Absolute β-convergence model

The catching-up process shows only the sign of the evolving convergence or divergence process. However, the absolute β-convergence model shows the intensity of convergence or divergence in select indicators across given geographical units. Table 2 displays the results of the absolute β-convergence model for child stunting in 174 countries. The rate of change in child stunting for the overall period, 1990–1995 to 2010–2015, is considered as a dependent variable, and child stunting for the initial period 1990–1995 is the predictor variable. The same process is used in piece-wise regression models for the sub-periods, 1990–1995 to 2000–2005 and 2000–2005 to 2010–2015. The results show divergent progress in child stunting ($\beta = 0{\cdot}1925$, $P < 0{\cdot}05$) across the countries during 1990–1995 to 2010–2015. Similar findings are observed when the absolute β-convergence models were conducted for sub-periods (1990–1995 to 2000–2005 and 2000–2005 to 2010–2015). The results indicate that the rate of decline in child stunting is not greater among countries with higher stunting prevalence in the initial period, thereby failing to provide evidence of catch-up towards countries with low stunting prevalence. The estimates of the speed of convergence or divergence suggest that the decrease in child stunting across countries was diverging at 7·04 % per year in 1990–1995 to 10·4 % per year during 2000–2005 to 2010–2015.

Factors explaining global divergence in child stunting

The conditional Barro-regression model is used to identify factors of global divergence in the rate of decline in child stunting between 1990 and 2015. Considering the collinearity across the predictors, we have modelled three separate regressions in Table 3. In these models, we regress the

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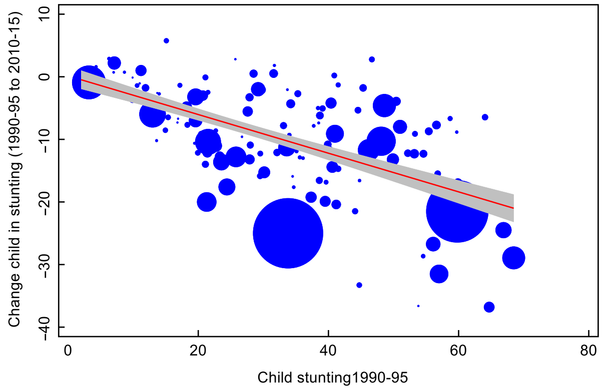

Fig. 3 (colour online) Catching-up plots: the relationship between the level of change in childhood stunting during 1990–2015 and its initial values in 1990–1995

annual rate of change in stunting levels during 1990–2015 by the initial level of child stunting along with eight other factors, which are categorised into basic amenities and health policies, socio-economic and climatic factors. The results across all three models show that stunting in the initial period ($\beta = -0{\cdot}323$, $P < 0{\cdot}05$, $\beta = -0{\cdot}402$, $P < 0{\cdot}05$, $\beta = -0{\cdot}519$, $P < 0{\cdot}01$) is negative and statistically significant, indicating conditional convergence. The earlier divergence is replaced with convergence after controlling for variation in basic amenities, socio-economic and climatic factors across the countries. Moreover, the findings also suggest that the current divergence in child stunting is due to variation in health policies and socio-economic conditions across countries.

Furthermore, each model presents the specific factors that are associated with diverging progress in child stunting across different countries. First, GDP per capita ($\beta = -0{\cdot}325$, $P < 0{\cdot}01$, $\beta = -0{\cdot}323$, $P < 0{\cdot}01$, $\beta = -0{\cdot}318$, $P < 0{\cdot}01$) is statistically significant and shows a negative relationship with the annual rate of change in child stunting across all three models. This finding suggests that higher growth in GDP per capita helps in reducing the child stunting net of other important factors. Second, poverty is statistically significant and positively associated with child stunting across all three models ($\beta = 0{\cdot}118$, $P < 0{\cdot}1$, $\beta = -0{\cdot}323$, $P < 0{\cdot}1$, $\beta = -0{\cdot}318$, $P < 0{\cdot}1$). Third, spending on health is statistically significant and has a negative relationship with the annual rate of change in child stunting ($\beta = -0{\cdot}492$, $P < 0{\cdot}1$, $\beta = -0{\cdot}512$, $P < 0{\cdot}1$). These findings suggest that inter-country variation in the growth of GDP per capita, rate of decline in poverty ratios and public health spending are major reasons behind the diverging progress in global child stunting. In particular, variations in public spending on health across countries are the biggest factor causing diverging progress towards the elimination of stunting. At an outset, *F*-statistics in all three conditional β-convergence models suggest ample evidence to conclude that our adjusted β convergence models fit the data better than the model with no independent variables.

Robustness checks

Kernel density plot

Figure 4 presents a Kernel density plot displaying child stunting distribution over the period, 1990–1995 to 2010–2015 across the world. We observe bigger peaks at higher values of child stunting across the years, signifying that the countries with higher child stunting are more in number in three periods. The number of peaks in the latest period 2010–2015 (three peaks) is greater than what we observed in the initial period, 1990–1995 (twin peaks), suggesting a growing divergence in child stunting across countries over the period. These results also support for multiple convergence clubs instead of grand global convergence. Thus, the results from Kernel density plots support our main findings from the absolute β-convergence model.

Absolute and relative inequality

The AID and Gini index are additionally used to measure trends in both absolute and relative inequality in global child undernutrition over time. The results suggest that AID for child stunting has decreased from 10·38 % in 1990–1995 to 8·15 % in 2010–2015. In contrast, the Gini index for child stunting has increased from 26·44 % in 1990–1995 to 31·49 % in 2010–2015 (Fig. 5). The rise in relative inequalities in child stunting further strengthen confidence in our main findings from the absolute β-convergence model that progress in child stunting over the period is diverging.

Discussion

Child nutrition is central to the human and economic development and has implications for future well-being. Although there is a large literature on child nutrition, previous literature has not investigated whether child stunting progress is diverging or converging across the world. Our study addresses this research gap by examining the convergence hypothesis across 174 countries, using robust parametric and non-parametric measures to evaluate the progress in child stunting from 1990–1995 to 2010–2015. Further, although there are previous studies that measured trends of inequality in undernutrition, most are specific to a country or a region.

Our findings are important from a policy perspective. They show that although progress has been made in reducing global child stunting over time, the relative inequalities between countries have increased over time. There is also evidence of a reversal or stalling of progress in some low-income and lower-middle-income countries. The catching-up plots and absolute β-convergence suggest that child stunting is diverging across our sample of 174 countries over the period 1990–1995 to 2010–2015. The findings are also validated through multiple robustness checks

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Table 2 Absolute β-convergence estimates for child stunting across world countries during 1990–95 to 2010–15

Periods	β-coefficient	95 % CI (lower-upper limit)	P-value	Adjusted R^2	Speed of divergence (% per annum)	No. of observations
1990–1995 to 2010–2015	0·1925**	0·052, 0 .333	0·007	0·034	−7·04	180
1990–1995 to 2000–2005	0·1143**	0·019, 0·209	0·019	0·0253	−6·66	180
2000–2005 to 2010–2015	0·2490**	0·054, 0·444	0·012	0·0291	−10·37	180

Significance levels:
$^{**}P<0·05$.

Table 3 Conditional Barro-regression model estimates: factors associated with divergence progress in child stunting across the world countries

	β-coefficient					
Variables	Model 1	SE	Model 2	SE	Model 3	SE
Lag value of dependent variable						
Child stunting in 1990–1995	−0·323**	0·148	−0·402**	0·161	−0·519***	0·185
Socio-economic variables (1990–1995)						
Log of poverty	0·118**	0·0508	0·105*	0·0535	0·107*	0·0570
Log of Gini index	0·262	0·336	0·264	0·355	0·242	0·364
Log of GDP per capita (in US $)	−0·325***	0·0873	−0·323***	0·0969	−0·318***	0·108
Log of female education (Age 15+)	–		−0·0432	0·152	0·0578	0·200
Basic amenities (1990–1995)						
Log % of GDP in health expenditure	–		−0·492**	0·248	−0·512*	0·263
Log of basic sanitation facilities	–		–		−0·154	0·194
Log of basic drinking water	–		–		−0·0803	0·380
Climatic factors (1990–1995)						
Air pollution	–		–		−0·0478	0·222
Constant	1·599	1·523	2·794	1·778	3·920	2·531
No. of observations	132		125		118	
Prob > F	0·000		0·000		0·002	
R^2	0·163		0·194		0·211	
Adjusted R^2	0·137		0·153		0·145	

Significance levels:
$^{*}P<0·1$.
$^{**}P<0·05$.
$^{***}P<0·01$.

Dependent variable: Annual rate of change in child stunting during 1990–1995 to 2010–2015.

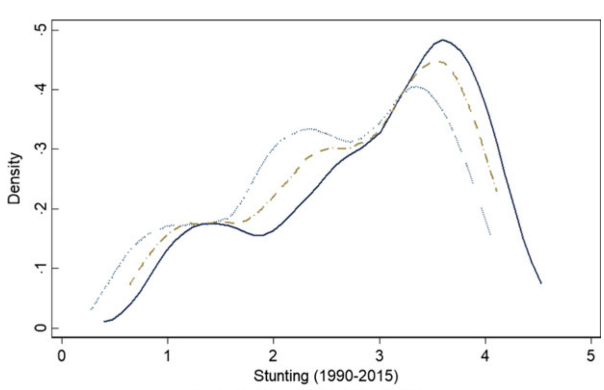

Fig. 4 (colour online) Kernel density plots: non-parametric test of convergence in childhood stunting across world countries during 1990–1995 to 2010–2015. ——, stunting (1990–1995); – · –, stunting (2000–2005); ·····, stunting (2010–2015)

using Kernel density plots, and absolute and relative inequality measures. Kernel density plots specify for emergence of convergence clubs rather than supporting for emerging global convergence. It may be because several laggard countries such as Djibouti, Papua New Guinea, Central African Republic, Niger, State of Palestine and Sierra Leone show negative progress, while countries such as India, Zimbabwe, Belarus and Barbados have experienced stalling progress in child stunting for the recent period, 2000–2005 to 2010–2015. Unless large lower-income and lower-middle-income countries from populous Asia and Africa make accelerated progress towards the elimination of child stunting, global convergence in child nutritional status is not possible. Further, our assessment of factors associated with divergent progress in child stunting using the conditional Barro-regression reveals that

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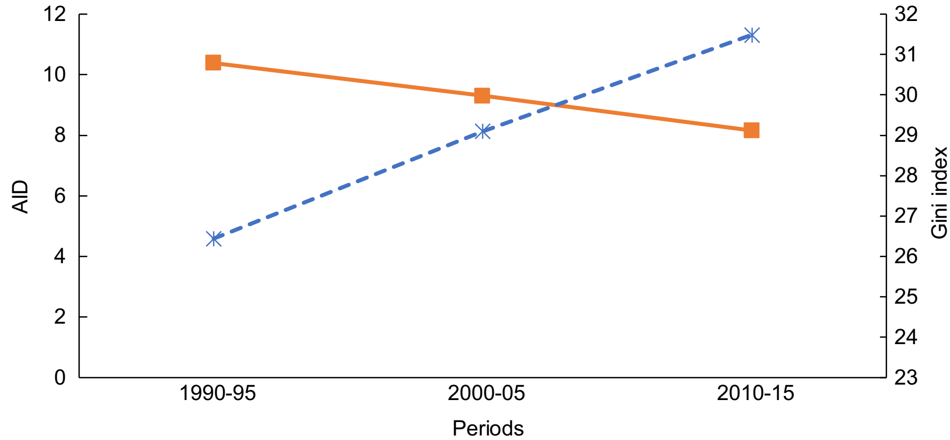

Fig. 5 (colour online) Trends in the AID for childhood stunting from 1990 to 2015. –■–, AID; -✳-, Gini. AID, average inter-country disparity

heterogeneous progress in GDP per capita, poverty and public health care spending are the critical factors behind the global divergence in child stunting.

Replacing current divergence with convergence in child stunting across needs concerted global policy on child nutrition. Our empirical findings show that along with economic growth, greater efforts are needed to address the nutritional needs of populations living below the poverty line by increasing state spending on health care and access to food. To be on track to achieve the SDG-2 targets at the global and the local level, the monitoring of the progress in child stunting towards the goal of 'Grand Convergence' should be carried out at least every 3- or 5-year interval. The use of convergence measures as a tool for observing the stable and continuous progress of any public health indicator, including child nutritional status, at the global and local level would help in priority setting of policies for progress towards SDG-2 by 2030.

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Supplementary material

For supplementary material accompanying this paper visit https://doi.org/10.1017/S136898002100375X

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