

Examining the Convergence of Human Development using Sigma Convergence Approach to Panel Data Analysis

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Abstract: - A special autonomy policy was implemented in Aceh in 2006, which differed in managing fiscal transfers from the central government. To this end, we examined the convergence of human development in districts/cities for thirteen years (period 2008-2020) as a form of development evaluation from the implementation of special autonomy. Using a sigma convergence approach to panel data sets sourced from the Central Bureau of Statistics (BPS), this study found a slow year-on-year movement of decreasing human development disparities. On the contrary, it can be discovered that solid evidence of absolute convergence in the 2011-2020 period, despite the differences between the 2008-2020 period, was applied. In line with these discoveries, it will take over a decade to achieve a steady state of living standards, equalization, and quality of human development between districts/cities. It could be the basis for policymakers to maintain a sustainable sense of special autonomy.

Key-Words: - Human Development Index, Convergence, Panel Data Analysis

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1 Introduction

The convergence hypothesis that originated from the views of Solow [1] and Swan [2] with the Neoclassical growth model by Evan & Karras [3] and Mazumdar [4] has become an exciting research theme for researchers in parts of the world. Most researchers focused on per capita income and labor productivity to test the convergence hypothesis (e.g., Baumol [5]; Baumol and Wolff [6]; De Long [7]; Dowrick and Nguyen [8]; Bernard and Durlauf [9]; Quah [10] and Zulham, Sirojuzilam & Saputra [11]. Furthermore, Barro [12] and Barro & Sala-i-Martin [13] expanded convergence analysis by adding explanatory variables, such as migration, life expectancy, investment, government consumption ratios, inflation rates, etc.

However, in recent decades researchers have devoted their attention to examining and investigating the convergence of the Human Development Index (HDI) after the United Nations Development Program (UNDP) published its 1990 Annual Human Development Report (HDR). HDI is considered a better and more comprehensive measure than income per capita for the level of welfare [4], [14], [15]. The same view is also expressed by Mayer-Foulkes [16]. They conclude that the socio-economic dimension is essential in

measuring welfare, not only based on the size of per capita income.

If explored in-depth, empirical studies of convergence in the context of living standards and socioeconomics or using one of the components of HDI indicators have been traced by leading researchers. Hobijn & Frances [17] reviewed the convergence of using a standard of living measure by including one indicator of HDI (life expectancy at birth), besides daily calorie supply, daily protein supply, and infant mortality rates indicators. His findings revealed that convergence in real GDP per capita did not imply convergence for other social indicators and the continuing inequality between privileged and unprivileged people in real GDP per capita and living standards. Mazumdar [4] investigated the convergence based on the classification of HDI development (high, medium, and low) and income per capita in 91 countries for thirty-five years (period 1960-1995). The findings reveal no strong evidence for HDI convergence and per capita income. It is noteworthy that Mazumdar's empirical study only analyses the HDI convergence and per capita income without including any HDI dimensions.

Sab and Smith [18] focused on education that found strong evidence of absolute and conditional

convergence following the idea of beta convergence. Mayer-Foulkes [19], meanwhile, focused more on life expectancy indicators to observe club convergence and concluded evidence of club convergence, while absolute convergence looks weak. Another study conducted by Neumayer [20] found evidence of convergence in living standards, including life expectancy and adult literacy rates, among other well-being indicators. Sutcliffe [21] investigated the relationship between globalization and world inequality, including testing HDI trends in 99 countries that revealed a coefficient of ever-decreasing HDI variation or evidence of convergence.

In further developments, some researchers are increasingly eager to examine the convergence of HDI between countries in parts of the world in detail and comprehensively, along with variations in econometric models and data. Noorbakhsh [22] investigated the convergence of HDI and its characteristics in 93 countries in Africa, Asia, the Pacific, Latin America, and Europe period 1975 to 2002 with the OLS regression model. Konya also applied the OLS regression approach, and Guisan [23] and Konya [24] observed the HDI convergence in European Union countries from 1975 to 2004. Furthermore, Mayer-Foulkes [16] analyzed HDI convergence and its inter-component interactions in 111 countries from 1970 to 2005 by expanding explanatory variables, such as FDI, urbanization, trade, and others, with static panel data regression models. Other researchers, Jordá and Sarabia [25], used OLS and PLM regression approaches to analyze the interaction of the composite welfare index covering the dimensions of health and education in analyzing convergence processes in 132 countries from 1980 to 2012. Goswami, Roy & Giri [26] recently implemented the Bootstrap Quantile Regression and Pooled OLS approach examining HDI convergence in 189 countries from 1990 to 2018.

In the regional context of each country, the issue of HDI convergence is increasingly being looked at by researchers. Interestingly, the overall results of empirical studies tend to be inconsistent. For example, in India, empirical studies of HDI and its convergence characteristics were conducted by Dholakia [27], Noorbakhsh [28], Ghosh [29], Roy [30], Gaur [31], and Banerjee and Kuri [32]. In Argentina, one of them was being researched by Capello, Figueras, Freille & Moncarz [33], who examined the role of regional public policy in

reducing the interprovincial development disparities in Argentina. His findings revealed that transfers from the central government to the provinces did not positively affect HDI convergence indicators, despite solid evidence of conditional convergence of each welfare indicator. Meanwhile, recently conducted by Yang, Pan & Yao [34] in China resulted in conditional convergence findings related to HDI, influenced by government spending in education and health.

In Indonesia's case, convergence-related research has long been initiated, but it is still focused on per capita income gaps and economic growth. Esmara [35] as early pioneer, followed by Uppal and Boediono [36], Akita [37], Hill and Weidemann [38], Hill [39], Akita and Lukman [40], Garcia and Soelistianingsih [41], Wibisono [42], Resosudarmo & Vidyattama [43], Hill, Resosudarmo, & Vidyattama [44], Heriqbaldi [45], Aritenang [46], Kataoka [47] and Kurniawan et al. [48]. However, very few studies examined the HDI convergence across Indonesia's regions. Recent studies have focused more on inequality and convergence of per capita income and economic growth before and after the implementation of special autonomy. Zulham et al. [49] outlined the impact of special autonomy on the convergence of economic growth in Aceh before and after the implementation of special autonomy. Another empirical study conducted by Jamal et al. [50] analyzed the success of district expansion to reduce economic growth inequality between districts in Aceh Province and the factors that influence it. Another recent study on Aceh's special autonomy was traced by Abrar et al. [51] but did not comprehensively review HDI convergence. The latest study was conducted by Miranti and Mendez-Guerra [52], using a spatial approach to analyze district-level HDI in Indonesia using a new HDI method during the 2010-2018 period.

Despite the various empirical studies of HDI convergence that we have put forward, the purpose of this study is not to validate or disprove theoretical models [53]. Instead, our primary goal is to examine the HDI convergence between cities as a form of development evaluation in scientific approaches to the sustainability of community welfare in Aceh and contribute to the HDI convergence literature. It is important to note that Aceh, as one of the regions in Indonesia that received Special Autonomy treatment in 2006, after a prolonged political conflict ended with peace in mid-2005 [54]. A devastating earthquake and tsunami also hit this area at the end

of 2004 [55]. Therefore, we will do this to increase knowledge related to the HDI convergence between regions in Aceh Province.

This article has three purposes. The first objective is to elucidate human growth development between districts/cities. The second goal is to scrutinize the convergence of human development sigma during the realization of special autonomy (estimation period). The third and final intention is to examine and investigate the absolute convergence of human growth between districts/cities from 2008 to 2020.

2 Literature Review

2.1 Human Development Index Measurement

Since the early 1990s, there has been a noticeable shift in the development paradigm from economic growth priorities to improving human well-being (e.g., Sen [14] and Dasgupta & Weale [15]). In 1990, the United Nations Development Program [56] published the first Human Development Report. The report introduces HDI, which measures human development in various countries. HDI is a composite index constructed from four leading indicators that reflect three dimensions: longevity, knowledge, and access to resources [22]. At first, the longevity dimension is measured by life expectancy at birth, knowledge is quantified by adult literacy and gross participation rates, and access to resources is assessed by the logarithm of real income per capita adjusted for purchasing power parity. In 2010, UNDP changed its HDI calculation methodology. Some indicators are replaced to be more relevant. The Combined Gross Enrolment Ratio indicator is revised with the Expected Years of Schooling indicator. The Gross Domestic Product (GDP) per capita indicator is transformed with the Gross National Product (PNB) per capita. In addition, the way of counting has also altered. The average arithmetic method was changed to a geometric average for calculating composite indices.

In HDI calculations, minimum and maximum values are set sequentially to convert the indicator into an index between 0 and 1. The maximum value is the highest observed value in a time series. Minimum values are regulated at 20 years for life expectancy, 0 years for educational variables, and \$100 for gross national income per capita. Each sub-index is calculated as follows:

$$DI = \frac{AV - MinV}{MaxV - MinV} \quad (1)$$

Where DI is Dimension Index, AV is Actual Values, MinV is Minimum Values, and MaxV is Maximum Values. Starting now, HDI is the geometric average of a three-dimensional index formulated as follows:

$$HDI = (I_{LEXP}^{1/3} \cdot I_{EDU}^{1/3} \cdot I_{INC}^{1/3}) \quad (2)$$

HDI is Human Development Index, LEXP is Life Expectation, EDU represents education, and INC is Income.

The Government of Indonesia is very committed to using HDI as one of the measures in development performance, including for provinces and regencies/cities. Failure to pursue high economic growth has made the Indonesian government prioritize human development as leading in accelerating development. The Indonesian government establishes HDI as an essential indicator in formulating the distribution of balance funds transferred from the central government to the regions. Likewise, special autonomy transfer funds distribution with the Aceh Government also uses HDI instruments. Human development performance primarily determines the allocation and distribution of special autonomy funds for each district/city.

In line with changes in HDI calculation methodology, the Government of Indonesia, through the Central Bureau of Statistics (BPS), began to apply the new HDI calculation method in 2014. The HDI indicators used in Indonesia are the same as UNDP, except for Gross National Product (PNB) per capita. The indicator is projected with per capita expenditure. New HDI methods are calculated from 2010 to the provincial and district/city levels to maintain the continuity of calculation. The following year has used new methods in calculating and presenting HDI between provinces and regencies/cities in Indonesia.

2.2 Human Development Index: Convergence: International Experience

The alternatives to per capita income, output, and productivity in examining the convergence hypothesis become interesting issues for researchers worldwide. UNDP published the first Annual Human Development Report (HDR) in 1990. Since then, researchers have begun to turn their attention to using HDI and the combination with the standard of living in observing the convergence process. Hobijn & Franses [17] reviewed convergence using

a standard of living measure by including one indicator of HDI (life expectancy at birth), besides the daily calorie supply, daily protein supply, and infant mortality rates indicators. His findings revealed that convergence in real GDP per capita does not imply convergence for other social indicators and the continuing inequality between privileged and unprivileged people in real GDP per capita and living standards. Neumayer [20] also focuses on convergence in living standards and, among others, uses HDI indicators, such as life expectancy and literacy. Unlike Hobijn & Franses [17], Neumayer [20] found evidence of convergence in living standards, especially life expectancy, infant survival, educational enrollment, literacy, and the availability of telephone and television.

Literature and other empirical studies that review HDI convergence varies widely in variable characteristics. Some focus on observing trends and HDI convergences, including each HDI component indicator, or on absolute convergence, and others test by adding conditional convergence. The findings are also diverse and tend to be inconsistent with each other. Mazumdar [4] analyzed HDI convergence in 91 countries from 1960 to 1995 based on HDI classification (High human development countries, Middle human development countries, and Low human development countries) and tested them with per capita income. His findings indicated divergence in HDI. Sutcliffe [21] reviewed the relationship between globalization and world inequality, including testing HDI trends in 99 countries that revealed a declining coefficient of HDI variation or evidence of convergence.

Another comprehensive study was conducted by Noorbakhsh [22]. She reviewed the rationale for expanding and developing the Solow model to explore the relevance of HDI convergence. Data from 93 medium HDI and low HDI countries and five-year HDI intervals from 1975 to 2002 revealed weak absolute convergence. The shreds of evidence were also reinforced by the verification results of various conditional β convergence models. She uses variables including foreign direct investment, trade, foreign aid, gross domestic investment, the average annual growth rate of public sector expenditure on education and health, all given as a percentage of GDP, and the number of telephone lines per population.

Other empirical literature analyzes the HDI convergence and determinant factors, such as Mayer-Foulkes [16] and Jordá and Sarabia [25]. Mayer-Foulkes [16] conducted a cross-country analysis of HDI components, income, life expectancy, literacy, and gross enrollment ratios for

111 countries from 1970 to 2005. Meanwhile, Jordá and Sarabia [25] analyzed living standards (including HDI) in different countries from 1980 to 2012 using the concepts of absolute convergence, sigma, and beta convergence. Using semiparametric specifications, the results revealed absolute convergence, sigma, and beta convergence in well-being as measured by HDI, although the convergence process only liners in the health index.

On the other hand, some researchers are only interested in analyzing HDI convergence trends. For example, Konya and Guisan [23] and Konya [24] analyzed countries that joined the European Union during the period 1975-2004 using HDI trends and the concepts of convergence β (absolute) and σ -convergence. The findings are fascinating, which show that relatively underdeveloped countries have succeeded in increasing their HDI faster than developed countries, although the convergence process is slow. Meanwhile, other researchers only analyzed one of the HDI indicators or specific sectors related to HDI, such as Sab & Smith [18], Mayer-Foulkes [16], and Panopoulou & Pantelidis [57]. Sab & Smith [18] empirically found a substantial and conditional convergence in education, while Mayer-Foulkes [19] focused on the life expectancy indicator, one of the HDI indicators from 1962-to 1997 in 159 countries. The conclusions found evidence of weak absolute convergence between countries despite club convergence. Panopoulou & Pantelidis [57] observed it from 1972-to 2006 and showed evidence of the convergence of health spending per capita among the 17 OECD countries that did not lead to health outcomes.

The literature related to fiscal transfer's effect on HDI convergence was examined more in-depth by Capello et al. [33] in Argentina for well-being indicators from 1970 to 2001. He also examined the role of local public policy in reducing interprovincial development disparities. Interestingly, the finding of redistributive transfer from the central government to the province did not positively affect the convergence of HDI indicators, despite solid evidence of conditional convergence of each welfare indicator. Meanwhile, Agarwal [58] highlighted Social Sector Expenditure and HDI in India from 1999 to 2008 and found that the portion of social sector expenditure in development expenditure was a significant determinant of HDI. However, real income per capita is comparatively more essential than the share of social sector expenditure in development expenditure.

Yang et al. [34] made the most recent contribution in China, which examined HDI in 31

provinces from 1997 to 2006. The results of his study resulted in the findings of conditional convergence. Some variables, such as government spending on education, health, construction infrastructure, and fixed-asset investment, positively affect the convergence of social development. He also used a weighted population analysis for HDI, but the results showed weak convergence among provinces.

2.3 Regional HDI Convergence in Indonesia

In Indonesia's regional context, empirical studies and research related to HDI convergence began to become the attention of researchers. Nevertheless, our search results related to regional HDI convergence literature in Indonesia are still limited compared to regional inequality convergence literature using per capita income, output, and productivity. Some relevant literature is expected to increase insight concerning observing the HDI convergence process. Vidyattama [59], using HDI variables and spatial approaches, observed whether the performance of neighboring regions (covering provinces and regencies) affected the speed of regional convergence in Indonesia from 1999 to 2008. His research revealed ongoing convergence in Indonesia in line with changes in HDI numbers, although the pace is decreasing. On the other hand, the influence of neighboring regions has little influence on the speed of convergence.

Other literature can be observed from Wakarmamua & Indrayono (2019), which examines the relationship between government spending and intergovernmental human development in Papua Province. Using structural equation modeling shows that capital expenditure as part of direct expenditure has positively impacted HDI. However, such empirical studies did not review convergence. The relevant study conducted by Syukriyah (2016) investigated the HDI convergence in 33 provinces in Indonesia for the 2013-2015 estimation period. He used the Generalized Least Square method (GLS) model. She discovered the sigma convergence of HDI and the absolute beta convergence of HDI between provinces in Indonesia during the estimation period.

The latest study was conducted by Ginanjar et al. [60] and Miranti and Mendez-Guerra [52]. Ginanjar et al. [60] found that human development inequality between provinces in Indonesia decreased from 2010 to 2019. Meanwhile, the study conducted by Miranti and Mendez-Guerra [52], using a spatial approach, analyzed district-level HDI in Indonesia from 2010 to 2018. His findings showed that the performance of neighboring regions (districts) had a

significant effect on the HDI convergence. In contrast, the gap between regions had decreased in HDI, and the education component tended to accelerate convergence compared to the components of life expectancy and expenditure.

3 Materials and Methods

This paper used district/city-level regions for panel data sets during the 2008-2020 period. Administratively, Aceh Province, which is one of the provinces in Indonesia, has 23 districts/cities that, until now, have not changed since the expansion of the territory in 2001. The panel data includes HDI sourced from the publication of the Central Bureau of Statistics (BPS) Indonesia. Table 1 shows descriptive statistics of HDI variables. 2008 was the beginning of the Special Autonomy establishment for the Government of Aceh by the Indonesian government as an implication of Law No.11 in 2006 concerning the Aceh Government. Therefore, 2008 is the fundamental reason for us to begin research and analyze its development until 2020 or around thirteen years of special autonomy implementation. In line with the initial year, we used HDI data (2008-2009) based on old calculation methodology (arithmetic) and HDI data (2010-2020) using geometric formulations published by BPS.

3.1 Convergence Model: Sigma and Beta Convergence

The convergence models used in this study are sigma (σ)-convergence) and beta (β)-convergence. The σ -convergence analysis is a time-lapse analysis to observe the occurrence of HDI convergence, carried out by calculating the coefficient of variation (CV), as done by Lei and Yao [61] and Jamal et al. [50] as follows:

$$CV = \frac{\sqrt{\frac{\sum(HDI_i - \overline{HDI})^2}{N}}}{\overline{HDI}} \quad (3)$$

In this case, CV = Coefficient of Variation of the HDI variable. HDI_i = HDI variable of districts/cities used in the study; \overline{HDI} = average of each HDI variable (HDI average); and N = the number of districts/cities in Aceh. If the HDI CV value decreases, it indicates that there is σ -convergence between districts/cities.

We tested the β -convergence hypothesis in the form of absolute convergence by following the

regression equations of the data panels used by Noorbakhsh [22], and Yang et al. [34] are as follows:

$$Y_{i,t} = \frac{1}{T} \ln \left[\frac{Y_{i,t}}{Y_{i,t-1}} \right] \frac{1}{T} [(\ln(Y_{i,t}) - \ln(Y_{i,t-1}))] \quad (4)$$

$Y_{i,t}$ in equation 4 is then used as a bound variable to equation 5 as follows:

$$Y_{i,t} = \alpha - \beta \ln Y_{i,t-1} + \gamma X_{i,t-1} + u_{i,t-1} \quad (5)$$

$$-\beta = (1 - e^{-\lambda}) \quad \text{or} \quad e^{-\lambda} = 1 + \beta$$

The specification model for the fundamental β convergence approach is written in equation four as follows:

$$\ln(HDI_{i,t}) - \ln(HDI_{i,t-1}) = \beta_0 + \beta_1 \ln(HDI_{i,t-1}) + u_{i,t} \quad (6)$$

The convergence process occurs when the coefficient of β_1 is less than 1, with the convergence velocity expressed as λ . In this regard, λ is the convergence velocity (e.g., Paas & Schilitte, [62]) which is formulated as follows:

$$\lambda = \frac{-\ln(1 + \beta)}{T} \quad (7)$$

Meanwhile, half-time is the time needed by a district/city in Aceh to halve the HDI gap to a stable state (Barro & Sala-i-Martin, [63]; Paas & Schilitte, [62]), using the half-convergence model (Paas & Schilitte, [62]), as follows:

$$H = \frac{-\ln(2)}{\lambda} \quad (8)$$

4 Results and Discussion

4.1 Descriptive Statistics and Human Development Index

This section summarizes HDI statistics and outlines HDI development by region during the estimation period. Table 1 summarizes HDI statistics for 23 districts/cities in Aceh from 2008 to 2020, including averages, standard deviations, and minimum and maximum amounts of total observations. In general, the average HDI increased dramatically at the beginning of the period (2008-2009) and declined in 2010. In the following year to the end of the estimated period, the average HDI continued to increase significantly, showing improvements in HDI components in regencies/cities in Aceh. In addition to knowing the variations in HDI each year

during the estimation period, the study displayed minimum and maximum HDI data.

It is noteworthy that the minimum and maximum HDI in the period 2008-2009 used the old HDI calculation method (arithmetic) to look different for the next period with the new (geometric) method. In the old method, the level of HDI disparity was deficient between high HDI and low HDI, which ranged around 9 points. However, it is recognized that the old arithmetic average method had disadvantages [56], [64]. For the new method, the level of disparity is higher than in the old method, and the value ranges from 20-to 21 points. However, the difference in points continues to decline, implying improvements toward a better quality of human development at the district/city level in Aceh.

Table 1. Descriptive Statistics of Cross--District: 2008-2020 (N = 299)

Year	Mean	St.Dev	Min	Max
2008	70,813	2,495	67,170	76,740
2009	71,281	2,476	67,590	77,000
2010	65,840	4,862	58,970	80,360
2011	66,376	4,842	59,340	80,870
2012	66,934	4,856	59,760	81,300
2013	67,386	4,885	60,110	81,840
2014	67,771	4,910	60,390	82,220
2015	68,586	4,917	61,320	83,250
2016	69,199	4,859	62,180	83,730
2017	69,766	4,766	62,880	83,950
2018	70,181	4,588	63,480	84,370
2019	71,051	4,668	64,460	85,070
2020	71,236	4,608	64,930	85,410

Figure 2 reveals the HDI development of Regencies/cities in Aceh during the implementation of special autonomy (period 2008-2020). In general, all districts/cities showed an increase in HDI, particularly the period 2010-2020 (the new HDI method). Areas with high-status HDI can sustain their achievements (although some have fluctuated ranking). In contrast, areas with low-status HDI (moderate status) are increasingly encouraged to improve human capabilities in each forming component. Looking at HDI per district/city, three areas with administrative city status are ranked at the top, such as Banda Aceh, Lhokseumawe, and Langsa, during the estimation period. These three cities have adequate public facilities for health services, education, and economic infrastructure. Banda Aceh is the central government of Aceh Province, and it is very reasonable to be ranked at the top of HDI with various public service facilities.

Lhoksumawe was once dubbed the petrodollar city because of the development of the oil and gas industry (90s era), fertilizer industry, and other supporting industries. Special Economic Zones (SEZ) are the central government's priority in encouraging industry and investment acceleration, one of them being developed in Lhokeumawe City. On the other hand, Subulussalam, one of the administrative cities, was in the lowest rank in human development during the estimation period. This city is an expansion of the region from Aceh Singkil, which had a definitive status in 2003. The Subulussalam City Government continues to encourage the acceleration of human development by implementing education, health development, and agricultural resource-based economic development focusing on oil palm commodities.

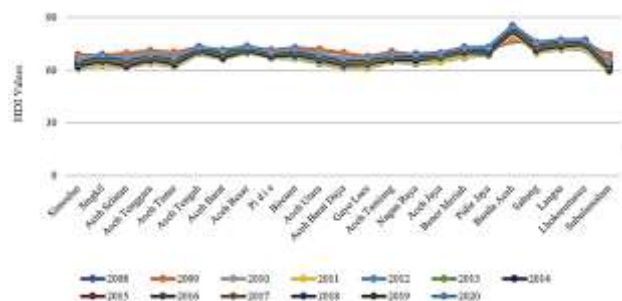


Fig. 1: HDI Development by Regencies/Cities in Aceh

Concurrently, HDI growth showed varying over the estimated period. Figure 4 shows HDI growth according to the division of areas in Aceh (west-south, north-east, central, and around the central government). During the implementation of special autonomy, the exceptionally high growth of HDI occurred in 2010 and was in the region around the central government. A similar fact is also seen in the north-eastern region, although its growth is still far from the central government area. A lower growth rate occurred in the west-south region in the same year. However, the high growth of HDI is more influenced by changes in HDI calculation methodology (from arithmetic methods to geometric methods). This fact shows almost no drastic difference in the HDI growth rate in each region from 2011 to 2020 (new HDI method). During this period, HDI growth rates in each region ranged from 1 to 3 percent. At the end of the estimation period, the new method shows that the HDI growth rate in the area around the central government is ranked second or not much different from the west-south region, after the central region. Two districts in the Central region (Gayo Lues and Southeast

Aceh), categorized as moderate HDI, contributed significantly to accelerating human development in the central region.

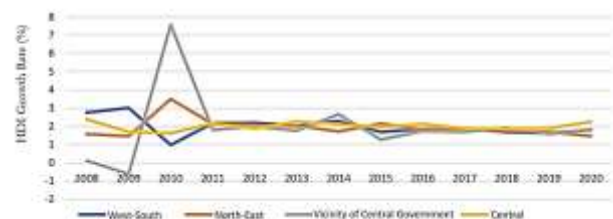


Fig. 2: HDI Growth by Regions

The coronavirus pandemic that hit Indonesia in early 2020, including Aceh, did not wholly worsen the achievement of accelerating human development in each region and showed a positive growth rate in human development performance.

4.2 σ - Convergence Estimation

β -Convergence is a necessary condition but not a sufficient condition for σ -Convergence. In practice, β -Convergence will be verified while σ -Convergence is verified [42]. We examine and analyze this convergence with static analysis using the coefficient of variation (CV). In this regard, we made two comparisons by including and excluding Banda Aceh City. It should be noted that Banda Aceh is the capital of Aceh Province and has adequate public facilities compared to other districts/cities in Aceh. Thus, the HDI of such cities tends to be higher, and it becomes interesting to examine the convergence process.

By including Banda Aceh city during the implementation of special autonomy for Aceh, or the period 2008-2020, the fall-off in human development inequality is relatively small, as shown in Figure 3. Likewise, there was no drastic difference in the decline in human development inequality during the estimation period without including Banda Aceh. However, overall, there is a difference in CV value between the presence and absence of Banda Aceh in the period 2010-2020, explaining the high CV value with Banda Aceh. High CV scores during the period can reflect high inequality in HDI, which is a noticeable difference in the achievement of human development progress between Banda Aceh City and other districts/cities in Aceh.

A very drastic difference during HDI inequality increase was seen in CV from 0.034 in 2009 to 0.072 in 2010. We ensure that all caused by differences in HDI calculations by the Central Bureau of Statistics (BPS) than previously using arithmetic methods to geometric methods. In the

2010 - 2020 period, there was a tendency to spread HDI inequality in Aceh to slowly decline, from 0.072 to 0.063 and from 0.056 to 0.049 (out-off Banda Aceh). This uncovering evinces that the HDI convergence process comes about between cities in Aceh, although the process tends to be flat and relatively slow. The findings are not much different from Vidyattama [59] and Ginanjar et al. [60] for regional contexts in Indonesia. Vidyattama [59] observed regional convergence in Indonesia, which found a decrease in HDI inequality during 2005-2008, which continued to slow down until the last observation period. Ginanjar et al. [60] found that the spread of human development inequality between provinces in Indonesia decreased from 2010 to 2019, but this was not significant because the rate of decline was relatively low. Decreases in human development disparities also occurred in the provinces in India between 1981-2001 [32] and the period 1990 to 2015 [65].

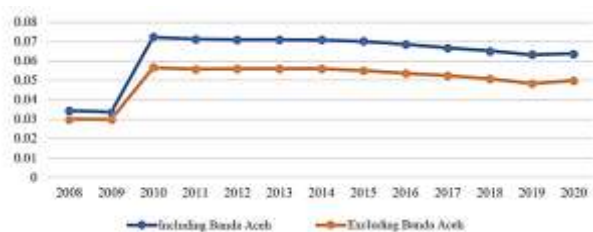


Fig. 3: Sigma Convergence of HDI Variation Coefficient Model

Considering the geographical area of the district/city in Aceh, covering the north-east (coastal), west-south (coastal), central (mountainous), and around the center of government, we also checked the CV during the implementation of special autonomy (see Figure 4). A decline in the high CV trend turned out in the central region, illustrating the decrease in the HDI disparity distance between regencies in the region. As we revealed initially, the cv trend that increased in the initial three years (2008-2010) was influenced by differences in HDI measurement methodology, including those occurring in the other three regions. Simultaneously, the other three regions showed a slight CV decline trend, meaning there are still disparities in human development between districts/cities in one area. During the observation period, we found that CV in the region around the central, which signified a higher disparity in human development. This fact reveals the striking difference in HDI between Banda Aceh City as the center of government, with the hinterland area of Aceh Besar Regency and Sabang City.

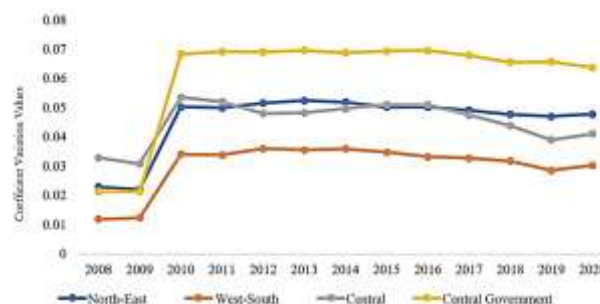


Fig. 4: Sigma Convergence of HDI Variation Coefficient

4.3 β -Convergence Estimation

In the literature, the beta convergence hypothesis explaining areas that were initially poor pursued and grew faster than those originally rich [13]. This process is seen in Figure 5, which shows that areas with low HDI in 2011 have grown faster than those initially high HDI from 2011 to 2020. Banda Aceh City, the capital of Aceh Province, with a high HDI status and ranked first HDI, showed a low average of HDI growth. It indicates evidence of beta convergence of the HDI process during the implementation of special autonomy in Aceh. This convergence process is affected by the faster growth of moderate HDI areas and by continuing a slowdown of HDI in high to very high districts/cities status. This discovery follows empirical evidence documented in the study by Ginanjar et al. [60] for the regional context of Indonesia, where areas with low HDI show above-average HDI growth and, conversely, areas with high HDI are showing below-average growth.

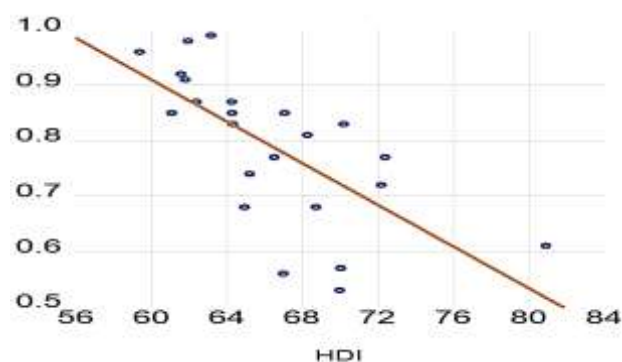


Fig. 5: Absolute Convergence of HDI

On average, at the beginning of 2011, several districts/cities had above average HDI, including Banda Aceh, Sabang, Langsa, Lhokseumawe, Aceh Jaya, Bireuen, Aceh Besar, Pidie, Bener Meriah, and Pidie Jaya. Interestingly, some districts/cities with below-average HDI scores tend to show above-average HDI growth, such as Subulussalam, Singkil, Simeulue, Southeast Aceh, Southwest Aceh, and

East Aceh, North Aceh, Gayo Lues, and Nagan Raya. The three highest cities with HDI scores (Banda Aceh, Langsa, and Lhokseumawe) showed below-average HDI growth from 2011 to 2020. That could be a positive sign in the future that the left-behind HDI areas continue to encourage the acceleration of human development. However, it will take a relatively long time to be in line with Banda Aceh city. For instance, in 2020, Subulussalam, the lowest-ranked HDI (value of 64.93), requires at least 20.48 points to increase its value to be equivalent to Banda Aceh City (value of 85.41). This point tends to decrease, indicating a decrease in human development disparity compared to 2011, at 21.53 points. In that year, the attainment HDI of Banda Aceh amounted to 80.87, and the HDI of Subulussalam amounted to 59.34. Likewise, Singkil (16.47 points), Gayo lues (18.19 points), South Aceh (18.29 points), Southwest Aceh (18.66 points), and Simeulue (19.38 points). In this regard, the regency/city government must realize health quality and education services utilized by the community, encourage local economic potential utilization, and accelerate investment for the community income sustainability.

Between 2011 and 2020, there was a shift in HDI ranking at the district/city level in Aceh. The allocation of HDI categories (BPS, 2020) to distinguish achievements between regions is categorized to incorporate very high ($HDI \geq 80$), high ($70 \leq HDI < 80$), medium ($60 \leq HDI < 70$), and low categories ($HDI < 60$). Since 2013, there has been no single district/city in the low category, although, in previous years, the category has always been achieved by Subulussalam City. Only Banda Aceh City achieved the high HDI category from 2010 until the final estimation condition. This achievement makes Banda Aceh one of the regions with the highest HDI in Indonesia (BPS, 2020). In addition, there are ten districts/cities for the high category, which was previously nine regions in 2018, including Lhokseumawe, Langsa, Sabang, Pidie Jaya, Bener Meriah, Bireuen, West Aceh, Central Aceh, Aceh Besar, and Pidie.

The 12 districts/cities in the medium category, previously 13 regions in 2018, including Subulussalam, Simeulue, South Aceh, Aceh Singkil, Southeast Aceh, East Aceh, North Aceh, Southwest Aceh, Gayo Lues, Nagan Raya, Aceh Jaya, and Aceh Tamiang. Changes in HDI ranking depend on the development of HDI supporting elements in each district/city; of course, there are different levels of development changes. The expansion of several districts/cities before implementing Special Autonomy is considered one factor in the

development progress difference between the new district and its parent district. In general, the construction of facilities is usually first established in urban areas so that the establishment will become less attention in remote districts. Some districts managed to maintain their rankings continuously, such as West Aceh. It was caused by several parent districts still maintaining some of their facilities, for example, office buildings, schools, health facilities, and economic support facilities. On the contrary, the three districts/cities resulting from regional expansion (Subulussalam, Simeulue, and Southwest Aceh) still occupy the lowest position in achieving human development. However, various development programs listed in the medium-term development plan (Rencana Pembangunan Jangka Mengengah) continue to be rolled out by the district/city government.

Table 2. Results of Absolute Convergence of HDI

Variable	Year		
	2008-2010	2011-2020	2008-2020
HDI 2008	-0.0825 (0.1373)		0.0571*** (0.019)
HDI 2011		-0.0312*** (0.009)	
<i>Implied λ</i>		9,68%	
<i>Half-life</i>		7,15	
F-statistics	0.36	10.71***	8.51***
(<i>p</i> -value)	(0.5542)	(0.003)	(0.008)
R Squared	0.016	0.3339	0,2885

Note: Dependent Variables: Growth Rate HDI; Parentheses are standard errors, ii) *p* -values are reported in case of F-statistics, and ***, **, and * denote significance levels at 1%, 5%, and 10%, respectively.

Table 2 depicts the estimated absolute convergence model results of districts/cities in Aceh in different estimation periods. The arithmetic HDI calculation method (period 2008-2010) confirms the result in a negative direction. We found unconditional convergence in this period but not supported by statistical figures, such as t-statistics and F-statistics, significant at 1 percent, 5 percent, and 10 percent levels. The combined HDI calculation methods for 2008-2020 reflect thirteen years of implementing Special Autonomy in Aceh. It emphasizes the process leading to the convergence of human development between districts/cities, even though it has not yet reached the steady-state conditions hypothesized in the classical theory of Solow Growth. That likely occurs fluctuations in the rise and fall of HDI growth in the 2008-2010 period, which is very drastic from using both HDI calculation methods. The results of

empirical studies of these two methods are in line with Wibisono's experience [42], who found the insignificant absolute convergence hypothesis for per capita income in the Indonesian regional context in the 1995-2000 period, which is likely caused by the 1997 economic crisis occurred in that period.

Using the geometric HDI calculation method, the second-period model (2011-2020) shows the coefficient of initial HDI growth towards a negative direction that corresponds to the initial and significant predictions. The HDI coefficient value is smaller than 1 (<1), meaning that HDI between districts/cities tends to converge (more evenly). The 'catch-up' phenomenon in the HDI development period implies that areas with lower HDI continue to do better to achieve higher income levels and a better quality of life during the study period. This finding is in line with sigma convergence analysis and regression results providing strong evidence against the existence of absolute convergence.

We found a negative and statistically significant coefficient (p -value < 0.001) for the model period, or significantly based on t -statistics and F -statistics at a rate of 1 percent, revealing substantial evidence of beta convergence over the estimation period. Thus, the results indicate that economies with lower initial HDI levels are pursuing higher HDI levels; thereby, a more uniform distribution of HDI achievements occurs in various economies from 2011 to 2020. The low R -squared value is 33.39% can be understood due to regression based on cross-section data [42]. The findings align with Vidyattama [59] and Miranti and Mendez-Guerra [52]. Vidyattama [59] found the HDI convergence (other than per capita income) in Sumatra and Java in Indonesia. In contrast, Miranti et al. found a decrease in the HDI gap between districts/cities in Indonesia. The homogeneity characteristics still play a role in the absolute β convergence for human development in Aceh; the difference between cities is only at the initial development level of HDI. It is not easy to find convergence if the characteristics are very heterogeneous [66].

In the global context, our discoveries are in line with Konya and Guisan [23], Jorda & Sarabia [67], and Asongu [68]. Konya and Guisan [23] found β -convergence of HDI during the period 1975-2004 among 101 countries, although the lagging countries took a long time, almost nine decades, to cover half of the retardation. Jorda & Sarabia [25] observed 132 countries in Western Europe, North America and Oceania, Arab States, East Asia, the Pacific, Europe and Central Asia, Latin America and the Caribbean, South Asia, Latin America, and Sub-Saharan Africa. Asongu [68] discovered the

absolute convergence of HDI for countries in North Africa from 1981 to 2009 and concluded that convergence in human development is faster than per capita income. Meanwhile, Ghosh [29] disclosed a definite convergence trend in HDI indicators, with estimated convergence rates varying from 1.25 percent to 4.23 percent per year. Chaurasia [65] found absolute convergence in human development across Indian states, although human development is still relatively low by global standards.

A λ value of 9.68 indicates that the speed of each district/city in Aceh during the period 2011-2020 to achieve steady-state conditions is 9.68% per year. These results confirm that the regional HDI convergence in Aceh over the past 11 years was relatively fast when special autonomy was implemented. It takes about 7.15 years to close half of the initial gap in human development in the district/city. In no more than a decade, it is expected that human development inequality in inter-district/cities in Aceh will continue to shrink. Overall, the HDI of Aceh Province also increased, which led to the HDI convergence in Aceh, where the districts/cities having low HDI can catch up with human development in developed districts/cities.

5 Conclusion

Aceh is one of the provinces in Indonesia that has the authority of Special Autonomy, apart from the Provinces of West Papua and East Papua. This special authority makes the Aceh Government more flexible in intervening in development policies in all sectors, including human development. It became the basis for us to fully evaluate and examine the welfare of inter-district communities during the implementation of Special Autonomy. This paper uses HDI as the primary measure to investigate the convergence hypothesis in all districts/cities in Aceh from 2008 to 2020 or thirteen years of special autonomy implementation. We use the concepts of sigma convergence and beta (absolute) convergence to examine human development convergence. Furthermore, sigma convergence means that HDI spread and disparity tend to decrease over time and beta convergence (absolute) implies a negative relationship between the initial level of HDI and its growth rate.

Using the Coefficient of Variation (CV) in investigating sigma convergence, we found results that corroborate evidence of sigma convergence of human development between cities from 2011 to 2020. HDI disparity declines despite its relatively slow movement from year to year. Despite the drastic increase in CV value at the beginning of the

estimation period (2008-2010), it was substantially more influenced by the methodology of arithmetic HDI calculations to geometric methods. The high decline in HDI inequality occurred in the central region, implying that areas with moderate status continue to accelerate human development towards a steady state. In the other three regions (North-East, West-South, and around the center of government), the decreased human development disparity movement is relatively slow, affecting the overall movement towards sigma convergence.

Regarding beta convergence, the results obtained from classical linear analysis show at least strong evidence of absolute convergence in human development over the estimation period (2011-2020). This finding reveals the areas whose HDI is constantly moving to pursue areas that have advanced human development. Overall, in the 2011-2020 period, convergence occurred at 9.68% per year. It takes about 7.15 years to close the initial gap in human development in districts/cities in Aceh. In this direction, the role of the central government in the form of special autonomy fund transfers is needed in supporting the acceleration of the human development convergence process in Aceh. Following regulations, the implementation of Special Autonomy in Aceh will end in 2027. Therefore, it is worth considering by the central government to extend the implementation of Special Autonomy, including increasing the allocation and distribution of transfers of this special autonomy fund for areas that are still low in HDI. The intervention is an essential factor in accelerating the convergence process focused on the field of human development in areas with lower HDI levels, such as Subulusalam, Simeulue, Aceh Singkil, and others. These conditions will help increase the growth rate for the convergence process of human development to be faster.

Finally, we suggest further research in the future to gain more knowledge and findings focused on HDI convergence, following its interactions between HDI components. In addition, to append data variation and econometric modeling, it will be interesting to focus on conditional convergence approaches by expanding explanatory variables in investigating HDI convergence. The relatively short (approximately 13-year) data availability and limited to one province should be a scenario for other researchers. It aims to present long-term data series and compare them between provinces in one country and between countries to help understand the continuous progress and trends HDI. Furthermore, methodology and modeling are expanded by examining spatial effects between

regions and dynamic effects and considering economic fluctuations due to the economic crisis and coronavirus pandemic.

This study focuses on using public budgets as a vital part of the transfer of Special Autonomy funds to priority sectors (including development programs and activities) may be further scrutinized. It will also be helpful to study the extent of the effectiveness of the use of the sector's budget is encouraging equalization of welfare and the continuous reduction of disparities in the region. In regions categorized as medium HDI, it is also necessary to implement optimal public budgets amid budget constraints concerning encouraging the acceleration of human development during the implementation of Special Autonomy. It would be more interesting to compare provinces and countries that both carry out broad autonomy to be a learning for equalizing the quality of human development in the future.

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