HUMAN DEVELOPMENT INDEX: A QUANTITATIVE REGRESSION ANALYSIS IN CONTEXT OF RICH AND UPPER-MIDDLE INCOME COUNTRIES

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Table of Contents

Abbreviations:

- GDP per capita: Gross Domestic Product Per Capita
- GDP: Gross Domestic Product
- HDI: Human Development Index
- SD: Standard Deviation
- UN: United Nations
- CV: Coefficient of Variation

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PART 1: Overview and data characteristic

1. Topic Overview

Gross Domestic Product (GDP) is a global benchmark to evaluate economic development in one country by computing the monetary value of national product's quantity manufactured within a year (Callen 2008). However, its limitations are biased and incomprehensive when societal process and evolvement are ignored; hence, researchers prompt a belief to widen the GDP's scope to involve life quality and societal well-being (Deb 2015). Human Development Index (HDI) is established in such landscape to generate a holistic view of economic development first founded by United Nations. The metric composes of domestic socio-economic elements to evaluate country development level through investigating multidimensional aspects of resident's livelihood (Chiappero-Martinetti et.al 2015). Specifically, HDI enfolds *education* measured by average years of schooling, *standard of living* assumed by taking all the values of goods and services of the national economy manufactured within a year divided by the population (GDP per capita), and *average life longevity* (Shah 2016; Roser 2014). This paper would discuss extensively the effect of macroeconomic indicators on HDI based on the dataset retrieved from World Bank, given list of variables (Appendix A). Combining mentioned list with HDI major components: *education, life longevity,* and *income*, the final suggested list of HDI determinants is:

VARIABLES	MEANING	SOURCE
gdpcap	GDP Per Capita (USD)	WB
gini	Gini Coefficient [0;1]	WB
ge	Government Effectiveness [-2.5; 2.5]	WB
lifeexpectancy	Life expectancy at birth	WB

Table 1. **Suggested list of HDI determinants (Source: WB)**

Regardless **gdpcap** and **lifeexpectancy** variables that have been proven to be **HDI**'s direct determinants, **gini** and **ge** variables are also involved. In fact, the data list is restricted where variable directly implies education component is not founded, thus, **gini** and **ge** could partially strengthen the report's credibility. **Gini** would support the interpretation on national living standard since it illustrates the income distribution of which information is hidden in GDP per capita (Hasell 2023). **ge** is measured by how well people perceive the quality of their public services and how resistant it is to political pressure (World Bank 2018). Therefore, this would be

an aggregate recommendation since public investment including improving educational level, financially enhancing social welfare accounts for this variable (Sakiru et.al 2020).

2. Data characteristic

	Min.	1st Qu.	Median	Mean	3rd Qu.	Max.	SD	CV (%)
***HDI** (x)*	0.511	0.723	0.782	0.783	0.858	0.941	0.092	11.7%
***pop** (million individuals)*	0.018	1.798	5.456	39.520	22.040	1337.705	148.735	376.4%
***growth** (%)*	-5.479	1.639	3.616	3.955	6.085	19.592	3.843	97.2%
***fdi** (billion USD)*	-20.770	0.315	1.802	17.300	11.220	264	43.650	252.3%
***gini** (x: range [0;1])*	0.251	0.331	0.403	0.408	0.480	0.729	0.095	23.3%
***ge** (x: range [-2.5;2.5])*	-1.564	-0.128	0.309	0.446	1.196	2.241	0.910	204.2%

Table 2. **Descriptive Statistics of all required variables**

Firstly, **HDI** illustrates an approximately desired bell-shaped curve representing normality in data distribution where difference between Mean (0.783) and Median value (0.782) is only 0.001. Country with highest **HDI** is Switzerland with 0.941 point, and metropolitans of Europe also dominates the top 10 of very high HDI index where there is only 1 country could exhibit its presence in this podium: United States with 8th ranking. Assuming in nonspecialized manner, Europe's HDI displays overwhelming preponderance over the sample's average value (0.783). With similar pattern of modest skewness, small gap between Mean (0.408) and Median (0.403) value of **gini** is 0.005. Within the range from 0 to 1, this variable's Mean value potentially suggests a moderate level of income inequality within 2 country groups in 2010: wealthy and upper-middle income.

Opposite pattern of data distribution founded in **gini** and **HDI** is **pop** where Mean is ~7 times higher than Median (39.52M versus 5.456M individuals). This excessive difference initiates skewness where upper extreme values impact on raising the Mean value (Khorana et.al 2022). As proof, China (1337.705M) dominates to be a main driver for the positively skewed distribution since Mean is more sensitive to outliers than Median (Khorana et.al 2022). Likewise, **fdi** also

presents an uneven data distribution as Mean is ~9 times larger than Median (17.300bilUSD versus 1.802bilUSD). Noticeably, there are negative values in **fdi** and Hungary and Denmark record most extreme values in lower bounds, -20.770bilUSD and -11.767bilUSD respectively. In 2010, these two countries' economies might experience plunge losses, disinvestment by foreign investors compared to new capital flows into the economies (OECD n.d.).

Another distribution pattern is slighter skewness compared to **pop**'s and **fdi**'s and heavier than **HDI**'s and **gini**'s. This pattern applies to **growth** and **ge.** The skewness of **growth** is a result of a 0.339% gap between Mean (3.955%) and Median (3.616%). Noticeably, negative **growth** rate as Min: -5.479% could imply a recession endured since economy with weak trading activities, low productivity, commonly has negative rate (RBOA n.d.; Anderson 2023). However, to strengthen the assumption on recession requires evidence of rising in unemployment rate. Regarding **ge**, its Mean is relatively low: 0.446 within its range (-2.5 ; 2.5) (World Bank n.d.). This general gloomy and unfavorable score caused by the wide gap between the Min and Max value; this could indicate the low credibility of government commitments to the policies that aims public services quality improvement, social welfare bettering, etc. (World Bank n.d.). Back to its data distribution, **ge**'s skewness is formulated based on similar pattern of calculating the difference between Mean and Median (0.446 – 0.309 = 0.137).

In terms of variance, another descriptive measurement is added: Coefficient of Variation (CV):

$$CV = \frac{SD}{Mean} \times 100\%$$

CV is more convenient in learning two or more variables' data variability that have different scales (Hayes 2023). Therefore, its nature is applicable here where variables have different units (currency, individuals, times, range).

pop variable inherits the highest CV (376.4%), hence population sizes recorded across countries in the sample set spreads out from the Mean and **pop** would endure highest sensitivity to changes in Mean. Followed by **pop,** the descending order is **fdi, ge, growth, gini, HDI**. HDI has lowest percentage as this data is least volatile and has least noise.

PART 2: Initial Estimation

1. Variable expectation

Model 1: Simple Linear Regression Model

$$\widehat{hdi} = \widehat{\beta_0} + \widehat{\beta_1} ge$$

Model 2: Multiple Regression Model

$$\widehat{hdi} = \widehat{\beta_0} + \widehat{\beta_1} growth + \widehat{\beta_2} fdi + \widehat{\beta_3} gini + \widehat{\beta_1} ge$$

With **gini** and **ge**, their impact on **HDI** in this model is expected to align with the theoretical expectation mentioned above. More specifically, **gini** illustrates the degree of income distribution range varying from 0 as perfect equality and 1 as perfect inequality (Hasell 2023). Therefore, when **HDI** composes multidimensional indicators aming to increase equitable development, the lower **gini** is more favorable; **gini** is expected to be negative significant on **HDI**. Moreover, the effect of **gini** on **HDI** also varies across countries, for instance, boosting inequality such as boosting GDP per capita at countries associated with high level of gini could manipulate an increase in **HDI** but severely hurt the nation in long run (Thiel 2016).

Regarding **growth**, it is an inclusive growth where an economy earns accelerating rate compared to its previous year, its impact on welfare improvement also makes presence (Abdul and Sidharta 2017). However, **growth** shall have negative association with **HDI** in certain context such as that of countries with extremely high rate; in such case, development in human capital is not correlated or impact of excessive growth in the economy might endure weak on HDI since these two paces (economic growth and human development growth) are incrementally unmatched; economic aspects are more weighted in investment compared to societal improvement considerations (Mandegar and Olsson 2023; Ramadhani 2021; Nam and Ryu 2023).

Although **fdi** has firm proof for its positive impact on HDI in developing nations, the general nature of FDI could not draw enough fraction to drive towards enhancement in HDI (Sharma and Gani 2005; Nam and Ryu 2023). Therefore, this variable is predicted to have no effect on HDI.

2. OLS

	(1)	**(2)**
VARIABLES	**Single**	**Multiple**
growth		-0.002
		(0.002)
fdi		0.000
		(0.000)

gini		-0.385***
		(0.072)
gee	0.072***	0.051***
	(0.008)	(0.008)
Constant	0.751***	0.923***
	(0.008)	(0.031)
Observations	88	88
R2	0.510	0.651
Adjusted R2	0.505	0.635

*Note: Robust standard errors are given in parentheses. *p<0.1; **p<0.05; ***p<0.01*

Table 3. **The statistical effect of listed variables on HDI**

PART 3: Interpretation

1. **Goodness-of-fit**

Model 1:

$$\widehat{hdi} = 0.751 + 0.072ge$$
$$(0.007684) \quad (0.007618)$$

$n = 88, R^2 = 0.510, Adjusted\ R^2 = 0.505$

Model 2:

$$\widehat{hdi} = 0.9226 - 0.002growth + 0.000fdi - 0.385gini + 0.051ge$$
$$(0.031) \quad (0.002) \quad (0.000) \quad (0.072) \quad (0.008)$$

$n = 88, R^2 = 0.651, Adjusted\ R^2 = 0.635$

Goodness-of-fit-R-squared (R^2) is a well-applied coefficient of determination, this measurement displays degree of variance in response variable that could be interpreted by predicted coefficient of predictors within a regression model (Buteikis 2020). Comparing two models' R^2, Model 2 is more favorable with higher value ($R^2 = 0.651$), 65.1% of HDI's elasticity could be explained by all independent variables within Model 2 (**growth, fdi, gini** and **ge**). While Model 1, only 50.1% variability of **HDI** could be interpreted, ceteris paribus.

However, in accordance with Wooldridge (2019), R^2 is less favorable since the proportion would never reduce when adding new independent variable to the model, thus, adjusted R^2 ($\bar{R}^2$) would penalize the regressors and restrict the inflated value. $\bar{R}^2$ of Model 2 still dominates over Model

1's (0.635 > 0.505). With similar interpretation construction, 63.5% of changes in HDI could be interpreted by all Model'2 predictors whereas 50.5% HDI's changes is interpreted by one independent variable (**ge**) in Model 1.

2. F-test

From this section onwards, a significance level (α) is chosen at 5% to apply for all hypothesis testing to balance between the type I error caused by smaller α (1%) and type II error caused by higher α (10%).

H_0: $\beta_{growth} = \beta_{fdi} = \beta_{gini} = \beta_{ge} = 0$

H_1: At least one predictor has statistical effect on the dependent variable

Null hypothesis is overwhelmingly rejected based on p-value approach.

Model 2 p-value is remarkably smaller than the chosen significance level ($\alpha = 5\%$) (2.2e-16 ~ 0.00000000000000022 < 0.05). Therefore, null hypothesis (H_0) is theoretically rejected at 0.05 significance level in favor of alternative hypothesis (H_1). Besides, the hypothesis rejection also implies that there is enough evidence to assume that at least one Model 2's predictor is statistically significant when α equals 0.05. In term of non-technical interpretation, Model 2, the multiple regression model involves 4 predictors namely: **growth, fdi, gini, and ge** have at least one variable is usable in explaining the elasticity of independent variable-HDI.

3. T-test

Variable	The hypothesis	T-test results
gini	H_0: $\beta_{gini} = 0$ H_1: $\beta_{gini} \neq 0$	The gini variable displays clear evidence to be statistically significant at the 0.05 level of significance (α) since p-value = 7.86e-07 (~0.000000786 < 0.05).
ge	H_0: $\beta_{ge} = 0$ H_1: $\beta_{ge} \neq 0$	The ge variable also shares the same result with gini variable for being statistically significant at 0.05 significant level (α). Its p-value scores even smaller = 2.56e-09 (0.00000000256 < 0.05)

Table 4. **Results of t-tests for each significant variable in Model 2**

The hypothesis stated follows a template:

H_0: $\beta_k = 0$: The k variable has no statistical impact on HDI

H_1: $\beta_k \neq 0$: The k variable imposes statical impact on HDI

Growth and **fdi** are not listed in this table since they are both insignificant variables with p-value$_{growth}$ = 0.289 (>0.05) and p-value$_{fdi}$ = 0.499 (>0.05). Hence, their t-test results fail to reject the null hypothesis of having no effect on HDI.

4. Slope Coefficient

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	9.226e-01	3.105e-02	29.713	< 2e-16 ***
growth	-1.738e-03	1.628e-03	-1.068	0.289
fdi	9.764e-14	1.439e-13	0.679	0.499
gini	-3.854e-01	7.212e-02	-5.343	7.86e-07 ***
ge	5.109e-02	7.649e-03	6.679	2.56e-09 ***
Residual standard error: 0.05555 on 83 degrees of freedom				
Multiple R-squared: 0.6514,		**Adjusted R-squared:** 0.6346		
F-statistic: 38.78 on 4 and 83 DF, **p-value**: < 2.2e-16				

Table 5. **Regression Estimate Results of Model 2 using OLS**

In Part 1 and detailed expectations of each Model 2's independent variable, it approximately fits the expectation and research proofs. However, it is surprising that growth's slope coefficient is impossible to interpret since **growth** is statistically insignificant; this means **growth** has no weight on **HDI** while empirical findings state its positive impact. However, this is arguably reasonable since **growth** is an inclusive metric and **HDI** shall be a predictor to explain elasticity in growth rate (Abdul and Sidharta 2017). Meanwhile, **ge** and **gini** align with the empirical findings mentioned earlier, the former is positive effect, and the latter is negative effect. However, thanks to the model, information on the negligible slope coefficients of **gini** and **ge**, is revealed since the empirical findings just drive towards proving the expected impact (positive or negative). This also aligns with Part 1's suggested list reasoning. **Fdi**'s slope coefficient is unable to interpret due to its insignificance, hence, the assumption that **fdi** has no weight on **HDI** remains true (Nam and Ryu 2023).

5. Model Selection

As assumed in section 1 of this part, Model 2 is more preferred with higher $\bar{R}^2$ indicating this model is a better fit since it could explain higher proportional elasticity of **HDI** (Wooldridge 2019). Moreover, according to UN, the composite attributes underlying **HDI** makes it more challenging for a simple linear regression model to interpret **HDI**'s variability not to mention Model 1's predictor, Government Effectiveness Index is not a major and direct component of **HDI** (UNDP 2010). Overall, Model 2 is officially chosen with better ability to explain HDI's fluctuations.

PART 4: Further Estimation

1. Dummy Variable

Model 3:

$$\widehat{hdi} = 0.933 - 0.001growth - 0.038highfdi - 0.413gini + 0.057ge$$
$$(0.031) \quad (0.002) \quad (0.023) \quad (0.073) \quad (0.008)$$

$n = 88$, $R^2 = 0.661$, $Adjusted\ R^2 = 0.645$

Variable	The hypothesis	T-test results
highfdi	$H_0: \beta_{highfdi} = 0$ $H_1: \beta_{highfdi} \neq 0$	The **highfdi** variable is not statistically significant with 0.05 significance level as its p-value = 0.098 (> 0.05).

Table 6. **T-test result summary of highfdi variable**

The null hypothesis of dummy variable ($H_0: \beta_{highfdi} = 0$) implying that **highfdi** is not statistically significant or has impact over HDI while its alternative hypothesis ($H_1: \beta_{highfdi} \neq 0$) states that the level of high or low FDI per capita would pose statistical impact on HDI. T-test result makes it fail to reject the null hypothesis at 5% significance level. Henceforth, the newly modified dummy variable (**highfdi**) has no statistical power over changes in dependent variable (**HDI)**. Therefore, interpreting its coefficient, as also known as the degree of changes in response variable could be explained by 1-unit change of predictor holding other variables constant, remains redundant and implausible.

2. Interaction Variable

Model 4:

$$\widehat{hdi} = 0.931 - 0.001growth + 0.035highfdi - 0.408gini + 0.055ge - 0.047ge * highfdi$$
$$(0.031) \quad (0.002) \quad (0.079) \quad (0.073) \quad (0.008) \quad (0.049)$$
$$n = 88\,, R2 = 0.665, Adjusted\ R^2 = 0.644$$

Variable	The hypothesis	T-test results
ge*highfdi	H_0: $\beta_{ge*highfdi} = 0$ H_1: $\beta_{ge*highfdi} \neq 0$	This interaction term between **ge** and **highfdi** variables is overwhelmingly not statistically significant holding significance level at 0.05 since its p-value = 0.338 (> 0.05).

Table 7. **T-test result summary of interaction term ge*highfdi**

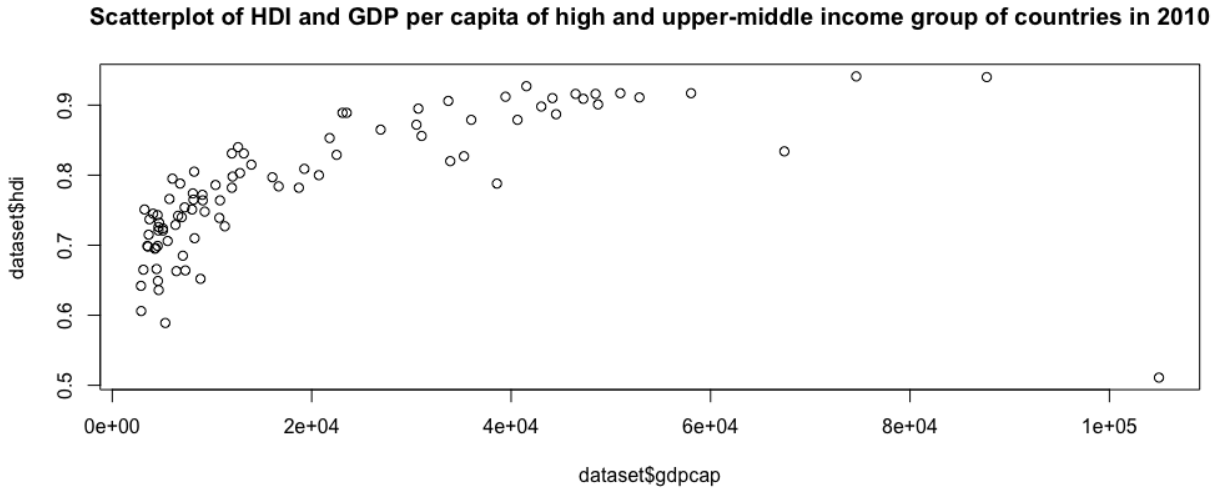
The interaction term between **ge** and **highfdi** (**ge*highfdi**) state its null hypothesis (H_0: $\beta_{ge*highfdi} = 0$) as follows: the impact of **ge** on **HDI** is similar for countries regardless of high FDI per cap and low FDI per cap (**highfdi**). While alternative hypothesis (H_1: $\beta_{ge*highfdi} \neq 0$) would state **ge**'s effect on **HDI** vary upon the classification: high FDI per cap and low FDI per cap (**highfdi).**

Like **highfdi,** the result of t-test fails to reject the null hypothesis at 5% significance level. Overall, interaction term **ge*highfdi** imposes zero statistical impact on HDI indicating that countries with high or low FDI per cap experience similar effect on HDI imposed by **ge**. And coefficient interpretation is again unnecessary and impossible.

3. Final model

Model 5:

Model 5 would apply reform to earn model statistical resilience in favor adding HDI's main component variables (**lifeexpectancy** and **gdpcap**), removing statical insignificant variables (**growth** and **fdi**) retrieved from 4 earlier models and applying functional transformation where needed. Therefore, the OLS methods would not consider $\bar{R}^2$ of linear models above since transformational models would be much more complex and advanced. The list of predictors on **HDI**'s variability is parallel to that of Part 1, **inflation** and **developing** variable would not be included due to lack of significance after applying functional transformation to the regression model. Transformation is necessary to avoid assumption violation and biased interpretation because the relationship between **gdpcap** and **HDI** is non-linear (Buteikis 2020); this could be witnessed via a scatterplot as follows:



Therefore, functional transformation including **logarithm (5a)** and **quadratic (5b)** term would be examined:

Model 5a:

$$\widehat{hdi} = 0.355 + 0.004lifeexpectancy - 0.241gini + 0.025ge + 0.022\log(gdpcap)$$
$$(0.173) \quad (0.001) \quad (0.082) \quad (0.012) \quad (0.011)$$

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.354963	0.172992	2.052	0.04333 *
lifeexpectancy	0.004120	0.001634	2.521	0.01362 *
gini	-0.240613	0.082339	-2.922	0.00448 **
ge	0.025330	0.011502	2.202	0.03042 *
log(gdpcap)	0.021749	0.011411	1.906	0.06012 .
Residual standard error: 0.0526 on 83 degrees of freedom				
Multiple R-squared: 0.6874		**Adjusted R-squared:** 0.6724		
F-statistic: 45.63 on 4 and 83 DF, **p-value**: < 2.2e-16				

Model 5b:

$$\widehat{hdi} = 0.540 + 0.003lifeexpectancy - 0.217gini + 0.021ge + 0.00001gdpcap - 0.000(gdpcap^2)$$

(0.100) (0.001) (0.060) (0.008) (0.000) (0.00000)

Coefficients	Estimate	Std. Error	t value	Pr(>|t|)
(Intercept)	0.540	0.100	5.405	6.22e-07 ***
lifeexpectancy	0.003	0.001	2.947	0.004179 **
gini	-0.217	0.060	-3.605	0.000535 ***
ge	0.021	0.008	2.597	0.011145 *
gdpcap^2	-0.000	0.000	-8.843	1.48e-13 ***
gdpcap	0.00001	0.00000	7.087	4.36e-10 ***
Residual standard error: 0.03772 on 82 degrees of freedom				
Multiple R-squared: 0.8412		**Adjusted R-squared:** 0.8316		
F-statistic: 86.9 on 5 and 82 DF, **p-value**: < 2.2e-16				

Applying logarithm term helps stabilize the variance and spread out the data (Appendix A), especially helps linearize the relationship between **gdpcap** and **HDI** for an unbiased model (Buteikis 2020). Majority of research applies natural logarithm form to illustrate the diminishing return attribute to HDI changes (Shah 2016); there is empirical evidence to apply quadratic form for **gdpcap**. Despite high and upper-middle income countries sample, 46 countries have HDI at medium range (≤0.65) (UNDP 2010). Therefore, Islam (1995) quadratic term application for such countries has founded a more complex relationship between **gdpcap** and **HDI:** 'inverted U'. A p-value approach is needed for elimination. Model 5b is more favorable with very small quadratic term's p-value at significance level (5%) while **log(gdpcap)** in Model 5a would be statically insignificant implying no power over HDI's elasticity (0.06012 > 0.05).

Variables	Coefficient	Interpretation
Intercept	0.540	When all predictors equal zero, HDI would equal ~0.540
lifeexpectancy	0.003	Holding other variables constant, **HDI** would increase by 0.03 when **lifeexpectancy** increase by 1 unit.

gini	-0.217	**HDI** would move down 0.217 whenever **gini** increases by 1 unit, ceteris paribus (parallel within its unit range [0;1])
ge	0.021	Unlike **gini, HDI** would inherit positive increase by 0.021 for every additional 1-unit increase in **ge,** ceteris paribus (parallel within its unit range [-2.5;2.5]
gdpcap	0.00001	The turnaround point is $x^* = \left\lvert\frac{0.00001}{2(-0.000)}\right\rvert = 0$[1] **HDI** would change by (0.00001+2*0.000*x) = 0.0001 if **gdpcap** increases by 1 unit (USD), ceteris paribus
gdpcap^2	-0.000	

However, biased suspicion raises for Model 5b. Since this work's independent variable list lacks education-related variable (i.e. mean years of schooling) but up to 83.16% HDI's variability could be interpreted by all predictors. Its gap with Model 5a is ~20%, this number shall cause overfitting model of which further prediction might be unreliable (Twin 2021).

PART 5: Conclusion

1. Findings summary

Part 1's descriptive statistics on assigned variables finds out data behavior like distribution, skewness degree and 3 out of 4 assigned variables are expected to affect HDI (**growth, ge, gini**). Part 2 and 3 reveals that HDI's multidimensional nature is aligned with the decision on multiple regression model usage to explain the index's variability; this means only models with more than 1 regressors are recommended onwards. Part 4 sorts out within the data availability and requested additional variables, **Model 5b** is the best model since dummy and interaction variables are insignificant at 5% significance level. However, this model selection is not satisfied due to variable limitations and overfitting concerns. Further investigation on different variables outside the suggested list is recommended; initiating the process with Model 5b is also time effective.

2. Policy Recommendations

There are various policies needed simultaneously for each dimension in HDI, we favor equitable educational access and employment opportunity due to income inequality in metropolitans

[1] The real calculation result is 0.000000000000000002098892

(Lengfelder 2016). High-income and demanding vocational skills shall be widely taught with the integration of technology usage instructions. The government should guarantee the equitable access to students at suburban regions not just pay attention to urban, high-paid fee schools. With highly-skilled-performed workforce, employee have wider job opportunities and selection along with better earnings hereby enhancing living standards. When suburban areas catch up with the modernization flow, they would become satellite cities support the major areas economically.

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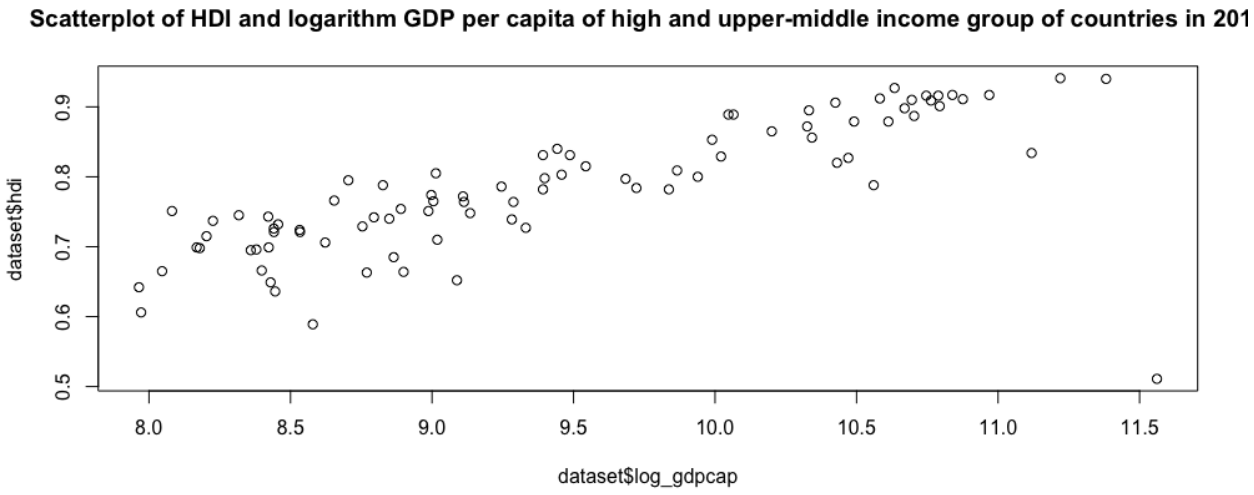
APPENDIX:

A – Variable List (World Bank)

VARIABLES	Meaning	Source
Country	Country's name	WB
Year	Year	WB
iso2c	Country's code	WB
fdi	Foreign Direct Investment inflow (USD)	WB
pop	Population	WB
gdp	Gross Domestic Product (USD)	WB
growth	GDP growth rate	WB
gdpcap	GDP per capita (USD)	WB
hdi	Human development index	WB
ge	Government Effectiveness	WB
gini	Gini coefficient	WB
inflation	Inflation rate	WB
Lifeexpectancy	Life expectancy at birth	WB
incomegroup	Income group	WB
developing	Dummy variable, = 1 if a country is a developing country	WB
Region_wb	Geographical region	WB

B – Logarithm transformation plot



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