Executive Summary

Using data from the Gapminder website, we examine the link between a nation's GDP per person and its yearly growth rate from 1960 to 2019. (www.gapminder.org). We examined the economic theory of convergence, according to which the GDP per capita of poorer nations will often "catch up" with that of wealthy countries by expanding more quickly. When compared to wealthy countries, we discovered that the poorer countries had a significantly greater annual GDP growth rate. We did not get any general convergence trend between 1960-2019 when we plot the GDP per capita and annual growth rate graph. But when observed on continent level, Asia, America and Europe showed small signs of convergence. When observed in the gaps of 20 years we find the period of greatest convergence was from 2000 to 2019. While Asia has shown more and more convergence as the time has increased America is the exact opposite. Europe and Africa varies for different time periods.

Countries Growth between 1969 and 2019

We calculate the annual growth rate of per capita GDP for each country. Not many nations have the same level of economic development as they had in 2019. Numerous measures, including GDP, population, and income, varied vastly. The nations with the highest and lowest per capita GDP growth rates would be a good place to start in order to understand this changing growth. The average growth in Annual GDP for each year starting from 1960 till 2019 was computed using the two values - the GDP of the nation in 1960 and the GDP of the nation in 2019. This would be a good metric to quantify a nation's growth and economic rise over the years. We have used categorized nations as "Fast Growth", which are nations with rapid economic growth in this period. Conversely, we have also termed nations with slow development rates in this period as "Slow Growth."

Figure 1:Fastest Growing Countries between 1960 and 2019

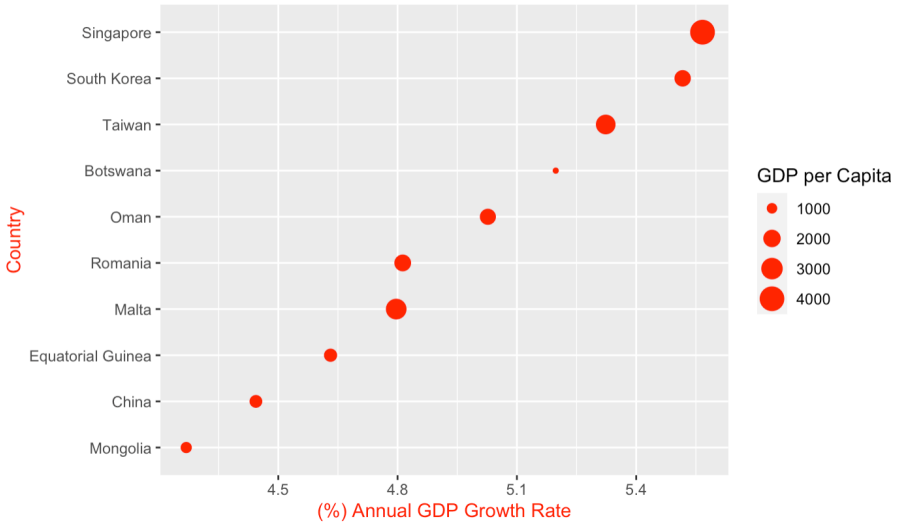


Figure 1 shows us the top 10 fastest growing nations between 1960 - 2019. Singapore, South Korea and Taiwan are the three top countries showing high rates of Annual GDP Growth Rate. It is interesting to note that, all the three countries belonging to this subset are from the continent Asia. Botswana, which is in Africa - is fourth on this list and was one of the poorest countries in the world in 1960. 6 out of 10 countries belong to Asia with 2 each going to Africa and Europe. Bigger points correspond to bigger population sizes.

Figure 2:Slowest Growing Countries between 1960 and 2019

Figure 2 shows us the top 10 slowest growing nations between 1960 - 2019. Congo, Central African Republic and Venezuela are the three countries showing the lowest rates of Annual GDP Growth Rate. 5 countries belong to African continent while 2 each to Asia and Oceania and 1 to the Americas.

In general we also observe most of the fast growing countries had lesser GDP per capita in 1960 when compared to slower growing countries. It will be interesting to investigate signs of convergence.

Convergence since 1960

We begin by examining the relationship between GDP per capita in 1960 and Annual GDP Growth Rate from 1960 to 2019. If we fit a linear model with GDP per capita in 1960 as our dependent variable and Annual GDP growth rate as our independent variable then a negative slope will indicate signs of convergence as it will show that poorer economies' per capita incomes will tend to grow at faster rates than richer economies. We will refer to slope as a reference point for evidence for convergence throughout the study.

Figure 3: Annual GDP Growth Rate vs GDP Per Capita between 1960-2019

Figure 3 shows us the relationship between GDP Capital in 1960 with annual GDP growth rate for all the countries in the dataset. There does not seem to be a very strong relationship between Annual GDP Growth Rate and GDP per capita. The slope of the line is pretty flat, and do not show any significant trend for us to conclude any signs of convergence. GDP per capita is right skewed so we use log scale to visualize.

Let us now look at the Annual GDP Growth rate and the GDP per capita on a continent level:

Figure 4:Annual GDP Growth Rate vs GDP Per Capita in 1960

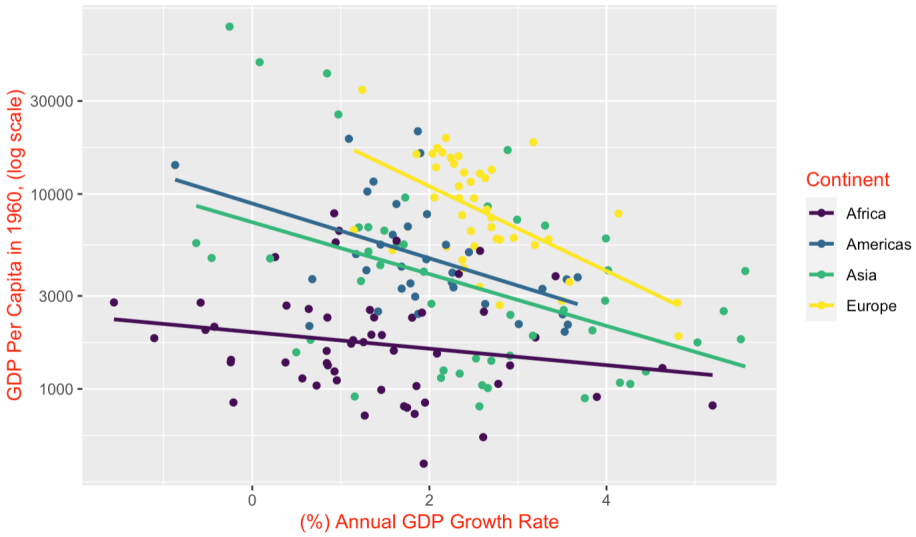


Figure 4 shows us relationship between GDP per cap and annual GDP growth rate continent wise. We fit linear model with countries belonging to respective continents and observe the slope individually. Continents like Asia, Europe and Americas show some level of convergence between richer and poorer countries.

Europe shows the most convergence between rich and poor countries as it has the most negative slope. It is followed by Asia and America which also show some convergence. Africa on the other hand, does not seem to show the convergence phenomenon as it has a very flat line. Rich countries and poor countries in Africa - both - have similar values for Annual GDP Growth Rate. It is hard to comment about convergence between richer and poorer continents as we have very few data points (Figure 12 in appendix) to make any conclusive statements.

To simplify further, we can get an idea of the magnitude of the effect of annual GDP growth rate on GDP per cap by fitting a robust linear model with additive terms for annual growth rate and continent against GDP per cap(base 10 log). (A model with an interaction provides a better fit, but is not as straightforward to interpret.)

	coef.est	coef.se
(Intercept)	3.38	0.05
gdp_rate	-0.11	0.02
continentAmericas	0.51	0.07
continentAsia	0.42	0.07
continentEurope	0.81	0.07

For every one-unit increase in the GDP per cap, our dependent variable decreases by about 23 percent(after converting back from log scale). The coefficients for the continents are relative to Africa. So the GDP per cap for a country outside Africa is modeled to be 163 percent for Asia , 224 percent for Americas and 545 percent for Europe higher than the GDP per capita for a country within Africa with the same annual growth rate.

Is convergence the same in different time ranges?

We will do the convergence analysis on 3 different time frames of 20 years between 1960-1979.

1960-1979 convergence Analysis

In Figure 5 we get a slightly positive slope which is a sign of divergence instead of convergence between rich and poor countries. An upward slope shows that rich counties have higher growth rate which is exactly opposite of the idea of convergence. So there is no convergence between 1960-1979. We can further analyze how countries within a continent behave in this time period.

Figure 5: Convergence Analysis between 1960-1979

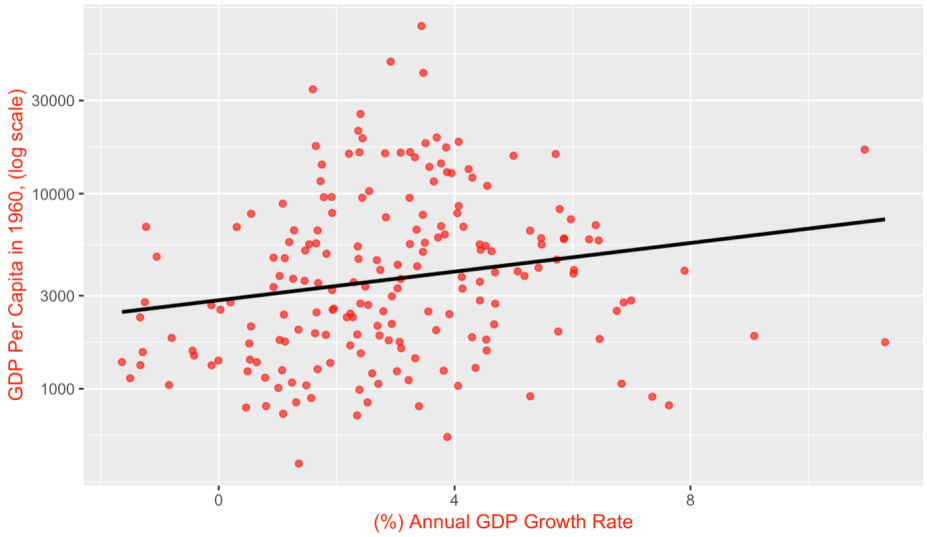


Figure 6:Convergence Analysis between 1960-1979

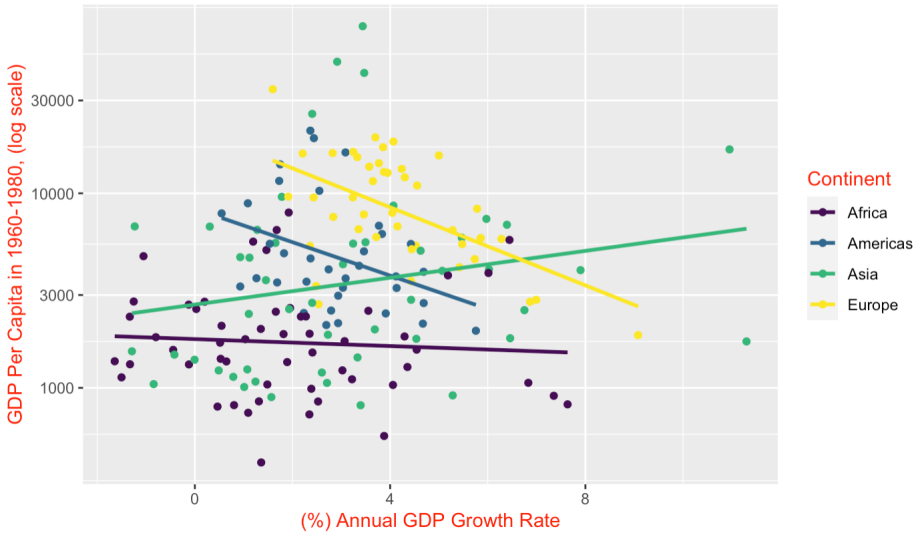


Figure 6 gives us different linear model lines for various continents. We observe that Americas and Europe are showing convergence phenomenon as they are having negative slope. Asia has a positive slope which shows signs of divergence. Africa on the other hand doesn't change and remains constant showing no signs of convergence. It is hard to comment about convergence between rich and poor continents as we have few data points to make strong conclusive statements.

1980-1999 CONVERGENCE ANALYSIS

Let us have a look at convergence as a whole between 1980-1999.

Figure 7 :Convergence Analysis between 1980-1999

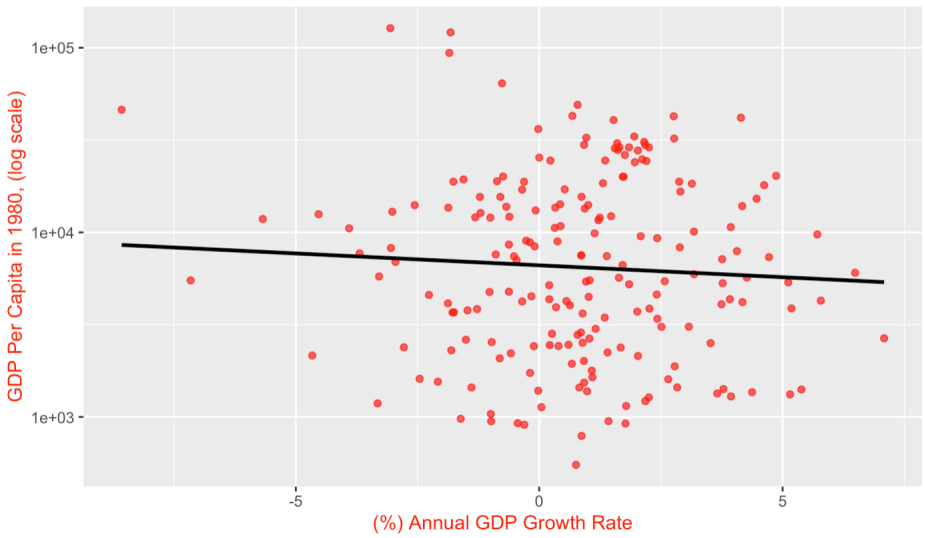


Figure 7 shows us relation between GDP per cap and annual GDP growth rate

between the time period 1980-1999. The trend is no where to be found as we get a very flat line and there is no sign of convergence between rich and poor countries during this time period. Let us dig deep and check for convergence on a continent level:

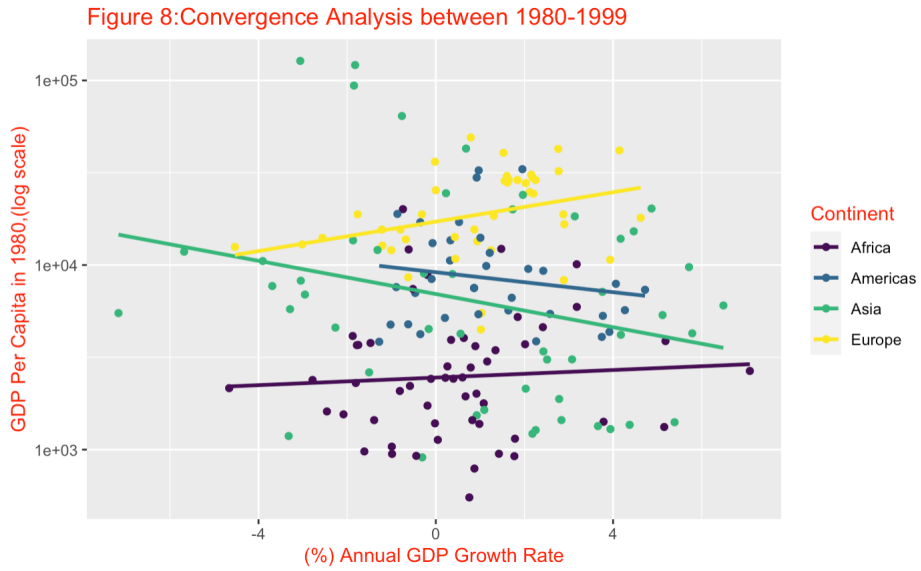


Figure 8 shows us 4 different linear model lines for 4 different continents. Asia is the only continent showing some signs of convergence due to its negative slope. Africa and Americas do not any show convergence with a flat line. Whereas Europe shows divergence with a positive slope which tells us rich countries performing even better than poor countries. It is plausible that African countries found it harder to grow even after 40 years which can be due to its lack of openness to international markets. It is hard to comment about convergence between rich and poor continents as we have few data points to make strong conclusive statements.

2000-2019 CONVERGENCE ANALYSIS

Let us have a look at convergence as a whole between 2000-2019.

Figure 9 shows us the relationship between GDP per capita and annual GDP growth rate. We observe a strong sign of convergence between rich and poor countries in this time period as slope is clearly negative. Let us look at convergence on a continent level:

Figure 9 :Convergence Analysis between 2000-2019

Figure 10: Convergence Analysis between 2000-2019

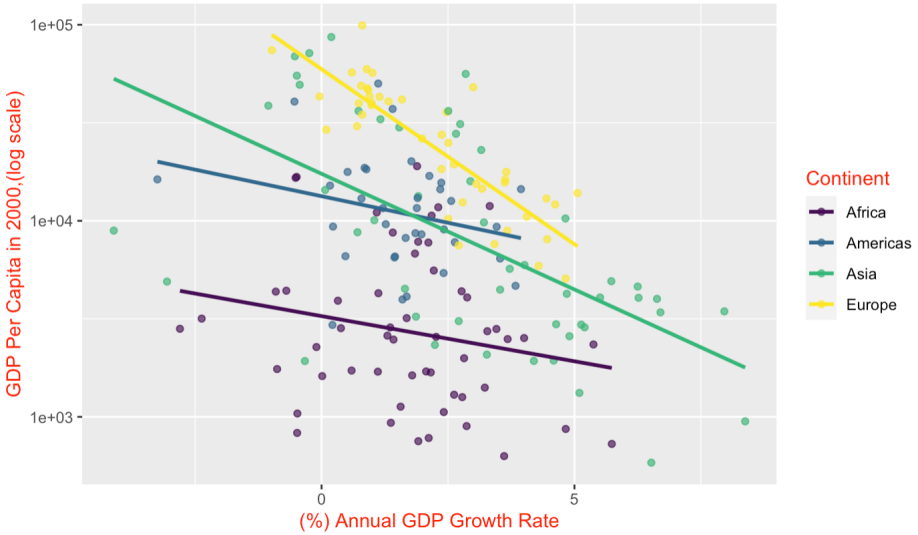


Figure 10 shows us 4 different lines of 4 linear models of various continents fitted on their respective country points. All 4 continents have a negative slope showing signs of convergence. Asia and Europe are continents showing high levels of convergence. Americas and Africa show very slight level of convergence with a very small negative slope. This time frame shows the highest level of convergence. It is hard to comment about convergence between rich and poor continents as we have few data points to make strong conclusive statements.

We will now observe the trend between various continents over the 3 time frames. Let's see how it changes for each continent.

Figure 11: Convergence Patterns for different Continents between 1960-2019
3 Time Frames of 20 years each between 1960-2019

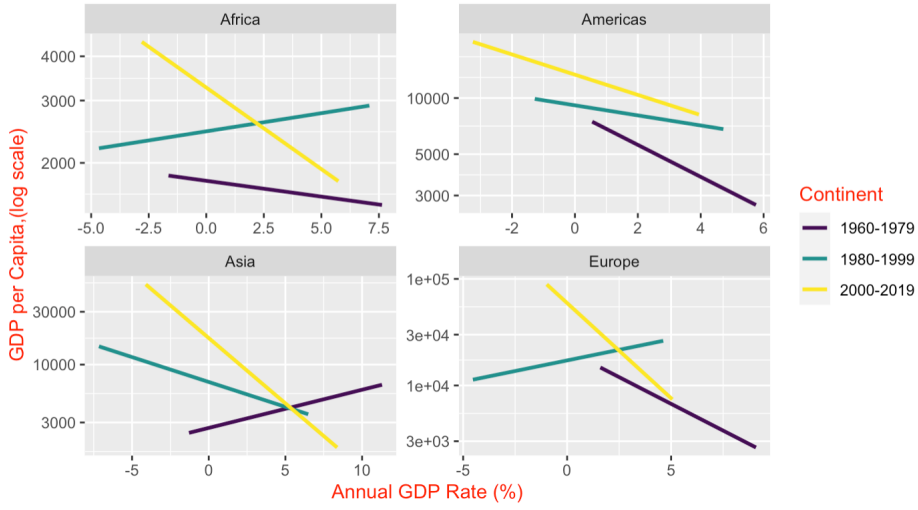


Figure 11 shows us the trend within continents between 1960-2019 split between 3 20 years time frames. Asia over the 3 time frames move towards convergence. It started with showing signs of divergence between 1960-1979 and then the showed convergence between 1980-1999 and then showing very strong signs of

convergence between 2000-2019 which was also the time for lot of Asian countries developing at a very high rate. Europe and Africa on other hand have very similar trends. Europe showed some convergence in the first 20 years and got steady like Africa in the next 20 years and both showing strong signs of convergence between 2000-2019. America has low convergence in general with slopes not being very high value and almost getting flat in the latest time frame.

CONLUSIONS

1. Country Growth : The economies with the highest annual growth rate are Singapore, South Korea, and Taiwan. The majority of the nations belonged to the continent of Asia. The economies with the slowest growth rates are Venezuela, Congo Democratic Republic, and Central African Republic. The majority of the nations with the weakest economic growth were found in Africa.

2. Convergence since 1960 : There is no overarching trend that allows us to make generalizations about convergence occurring from 1960 to 2019 as a whole. However, when we looked at convergence on a continent-level, we found that Europe showed the highest indicators, followed by Asia and America, and Africa showed none at all.

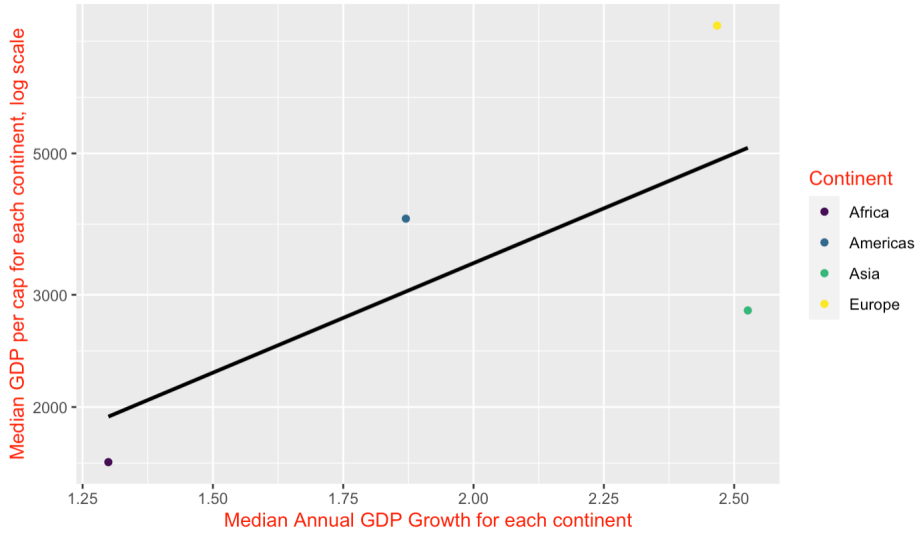
3. In the three 20-year time frames, we saw the greatest convergence between 2000 and 2019 on average. The evidence of convergence on the American continent have diminished over time. As time has gone on, Asia has experienced a rise in convergence. With the first 20 years displaying symptoms of convergence, there was a period of time between 1980 and 1999 when there was no evidence of convergence, and the period between 2000 and 2019 is when there are strong indicators of convergence. Africa did not exhibit any indicators of convergence for the first 40 years, up until 1999, and then there was strong evidence of convergence from 2000 to 2019.

4. It is very hard to make comment about convergence taking place between rich and poor continents throughout time as there are few data points to make conclusive statements. But from our analysis (Appendix Figure 13), there is strong evidence for no convergence between richest and poorest continent i.e. Europe and Africa. But Asia and America have shown some convergence as Asia's median growth rate has been higher than America.

Appendix

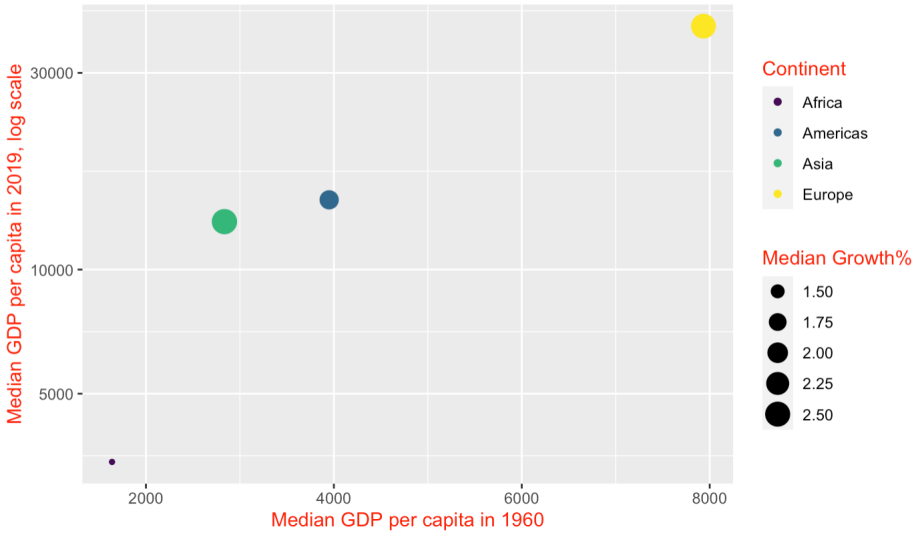
These are plot for reference to the main study.

Figure 12 : Convergence between rich and poor continents



It is very hard to make statements about convergence among rich and poor continents as there are few points for use to make any conclusive statements.

Figure 13: Convergence Analysis between Continents between 1960-2019



In figure 13 we observe that Africa and Europe do not show any signs of convergence as the difference between is a lot as one is the richest continent and other is poorest continent. But we see interesting trend between Asia and America as Asia being the poorer continent in 1960 has a higher median annual growth rate and has come closer to median GDP of America in 2019. Though it is hard

to conclude of convergence between a single point but there is a strong evidence indicating some signs of convergence present.