**Exercise 1. Using the data from the Penn World Table 10.1, available at http://www.rug.nl/ggdc/ productivity/pwt/**

* **Perform an unconditional β-convergence analysis for the period 1960-1990 and another one for the period 1990-2019 for all countries of the world for which data are available. How has the global income convergence pattern across countries changed over time?**

The results suggest that there has been a global income convergence pattern across countries over time, but the nature of this convergence has changed between the two periods analyzed.

In the first period (1960-1990), the analysis shows that there was unconditional β-convergence, indicated by the negative coefficient (-0.005) on GDPpc (log real GDP per capita). This coefficient is statistically significant at the 5% level. The negative coefficient implies that countries with lower initial GDPpc experienced higher average GDP growth rates during this period, leading to income convergence. The intercept term (const) of 0.061 is also statistically significant, indicating a positive average growth rate for all countries during this period. However, the R-squared value of 0.039 suggests that only a small portion of the variation in GDPpc growth rates can be explained by this model.

In the second period (1990-2019), the analysis shows a similar pattern of unconditional β-convergence. The coefficient on GDPpc is -0.006, which is statistically significant at the 1% level. This indicates that countries with lower initial GDPpc continued to experience higher average GDP growth rates, leading to further income convergence. The intercept term (const) is 0.078 and statistically significant, suggesting a positive average growth rate for all countries during this period. The R-squared value of 0.112 indicates that a slightly larger proportion of the variation in GDPpc growth rates can be explained by this model compared to the first period.

By comparing the two periods, it can be observed that the magnitude of income convergence has increased in the second period (1990-2019) compared to the first period (1960-1990). This is evident from the larger negative coefficient on GDPpc and the higher R-squared value in the second period. It suggests that the process of income convergence has accelerated over time, indicating a narrowing of income gaps between countries.

Figures 1 and 2 visualize the patterns of income convergence. The graphs show the average growth rates of GDPpc for different countries over time. In both periods, countries with lower initial GDPpc tend to have higher growth rates, demonstrating the convergence pattern. However, the figures also highlight that the income convergence has been more pronounced in the second period, with a steeper decline in growth rates for countries with higher initial GDPpc.

Overall, the results suggest that there has been a global income convergence pattern across countries, with countries starting at lower income levels experiencing higher growth rates and catching up to countries with higher income levels. The convergence process has strengthened in the more recent period, indicating a narrowing of income disparities between countries.

* **Perform a conditional β-convergence analysis for both periods, controlling for differences in population growth rates and investment shares (average over the period, both of these variables are available in the Penn World Table dataset). How does the interpretation of your results differ from that of the previous question?**

The results from the conditional β-convergence analysis, which takes into account differences in population growth rates and investment shares, provide a different perspective compared to the unconditional analysis conducted previously.

In the first period (1960-1990), the conditional β-convergence analysis shows that the coefficient on GDPpc (-0.007) remains negative and statistically significant at the 1% level. This indicates that, even after controlling for population growth rates and investment shares, countries with lower initial GDPpc experienced higher average GDP growth rates, leading to income convergence. The coefficient on the investment share (s) is positive and statistically significant (0.012), suggesting that countries with a higher average gross capital formation share had higher GDP growth rates during this period. The coefficient on population growth (n) is negative and statistically significant (-0.679), indicating that countries with higher population growth rates experienced lower GDP growth rates. The intercept term (const) remains statistically significant at the 1% level (0.113), suggesting a positive average growth rate for all countries during this period. The R-squared value has increased substantially to 0.237, indicating that a larger proportion of the variation in GDPpc growth rates can be explained by this model compared to the unconditional analysis.

In the second period (1990-2019), the conditional β-convergence analysis shows similar patterns as in the first period. The coefficient on GDPpc is now -0.011, which is statistically significant at the 1% level. This implies that countries with lower initial GDPpc continued to experience higher average GDP growth rates, supporting the notion of income convergence. The coefficient on the investment share (s) has increased to 0.022, and it remains statistically significant, indicating that countries with a higher average gross capital formation share had higher GDP growth rates. The coefficient on population growth (n) is negative and statistically significant (-0.361), suggesting that countries with higher population growth rates experienced lower GDP growth rates. The intercept term (const) is statistically significant at the 1% level (0.155), indicating a positive average growth rate for all countries during this period. The R-squared value is 0.223, indicating a slightly lower but still substantial improvement in explaining the variation in GDPpc growth rates compared to the unconditional analysis.

Comparing the two periods, the conditional β-convergence analysis reinforces the finding of income convergence, with countries starting at lower income levels experiencing higher growth rates, even after accounting for differences in population growth rates and investment shares. The coefficients on population growth and investment shares highlight their significant influence on GDP growth rates, with higher population growth rates associated with lower growth rates and higher investment shares associated with higher growth rates. The figures 3 and 4 depicting the conditional β-convergence patterns visually confirm the convergence trend observed in the analysis.

Overall, the conditional β-convergence analysis provides a more nuanced understanding of the income convergence patterns, accounting for the effects of population growth rates and investment shares. It confirms that income convergence has occurred globally, with countries at lower income levels catching up to countries with higher income levels, even after considering the impact of population growth and investment factors.

**Exercise 2. In their seminal paper A Contribution to the Empirics of Economic Growth, Mankiw, Romer and Weil include human capital in the Solow model and present empirical evidence about the role that education plays as a determinant of economic growth. You can find the data used in the paper here:** [**https://github.com/HariharanJayashankar/mrw1992**](https://github.com/HariharanJayashankar/mrw1992)**.**

* **Is the effect of human capital on economic growth different in African countries as compared to the rest of the world? Test this hypothesis making use of the model which is presented in Table VI.**

The regression analysis provides insights into the relationship between human capital and economic growth in African countries compared to the rest of the world.

The coefficients for the interaction terms in the table:

1. ln(H)xAfrica: The coefficient estimate is 0.169, and it is statistically significant at the 10% level (p < 0.1). This indicates that there is a significant interaction effect between human capital (H) and being in an African country on economic growth. The positive coefficient suggests that the impact of human capital on economic growth is larger in African countries compared to non-African countries. This highlights the importance of prioritizing education, skills development, and health in African nations to stimulate economic growth.

2. ln(Y)xAfrica: The coefficient estimate is -0.034, and it is statistically significant at the 1% level (p < 0.01). This suggests that there is a significant interaction effect between GDP (Y) and being in an African country on economic growth. The negative coefficient implies that the impact of GDP on economic growth is smaller in African countries compared to non-African countries. This may indicate structural challenges, such as limited infrastructure, institutional barriers, or unequal distribution of resources, which impede the translation of GDP growth into sustained economic development in African nations.

* **Is the speed of conditional income convergence implied by this model different in African countries as compared to the rest of the world**?

- The coefficient estimate for the variable ln(s) – ln (n + δ + g) is positive and statistically significant in the Africa column. This suggests that higher savings rates relative to the sum of population growth, depreciation, and technological progress contribute to income convergence specifically in African countries.

- The coefficient estimate for the variable ln(H)- ln (n + δ + g) is positive but only marginally significant at the 10% level in the Africa column. This indicates that human capital accumulation relative to population growth, depreciation, and technological progress may have a weaker effect on income convergence in African countries compared to other regions.

- The coefficient estimate for the variable ln(Y) (which represents initial income levels) is negative and statistically significant in the Africa column. This implies that African countries with higher initial income levels tend to experience slower income convergence.

In summary, based on the table, there is some evidence to suggest that the speed of conditional income convergence may differ in African countries compared to the rest of the world. Higher savings rates relative to population growth, depreciation, and technological progress contribute to income convergence in African countries specifically. However, the impact of human capital accumulation and the initial income levels on income convergence in African countries may be weaker compared to other regions.