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<u>Introduction</u>

The world's population is aging i.e., the number of older people is expanding faster than the number of young — but we probably don't realize how fast this is happening.

If the share, or proportion, of people over 65 is growing, the population is aging. Any age cohort above the median age of 28 of the global population is rising faster than that of any segment below the median. As of 2018, 65-year-olds, for example, have outnumbered those under 5 — a historic first. In 2050, developed countries are on track to have half as many people under 15 as they do over 60.

<u>Problem Description</u>

Population ageing is in many ways a demographic success story, driven by changes in fertility and mortality that are associated with economic and social development. Progress in reducing child mortality, improving access to education and employment opportunities, advancing gender equality, and promoting reproductive health and access to family planning have all contributed to reductions in birth rates. Moreover, advancements in public health and medical technologies, along with improvements in living conditions, mean that people are living longer and, in many cases, healthier lives than ever before, particularly at advanced ages.

But, this age mix is unevenly distributed among nations. The more developed countries have a higher median age than the developing countries. These developing countries with higher population growth rates have lower median ages. An important economic indicator that seems to be affected by this shift in age mix is the GDP growth rates of countries. Developed countries like Japan, USA etc. could hurt their GDP growth rates due to these higher age mix and hence comes into play the factor of migration and globalization of young population to these countries to keep their GDP growth rate positively increasing.

<u>Project Outline</u>

- Data collection and cleaning

- Creating visualizations to see trends

- Coming up with the hypothesis

- Creating interactive plots

- Results and Analysis

- Problems faced and deficiencies of our model

- Conclusion

- Individual learning outcomes

Potential Approaches to Study this problem:

1.After considerable reading on this topic and skimming through the abundance of datasets on various platforms, we first decided to plot the trend of increase/decrease in median ages for various countries available in the dataset (1950 – 2015). An interactive plot with a country list with the feature of hovering on the pointers on the line to view the median values was created. Below are few snippets that brought up some interesting questions and led to further analysis.
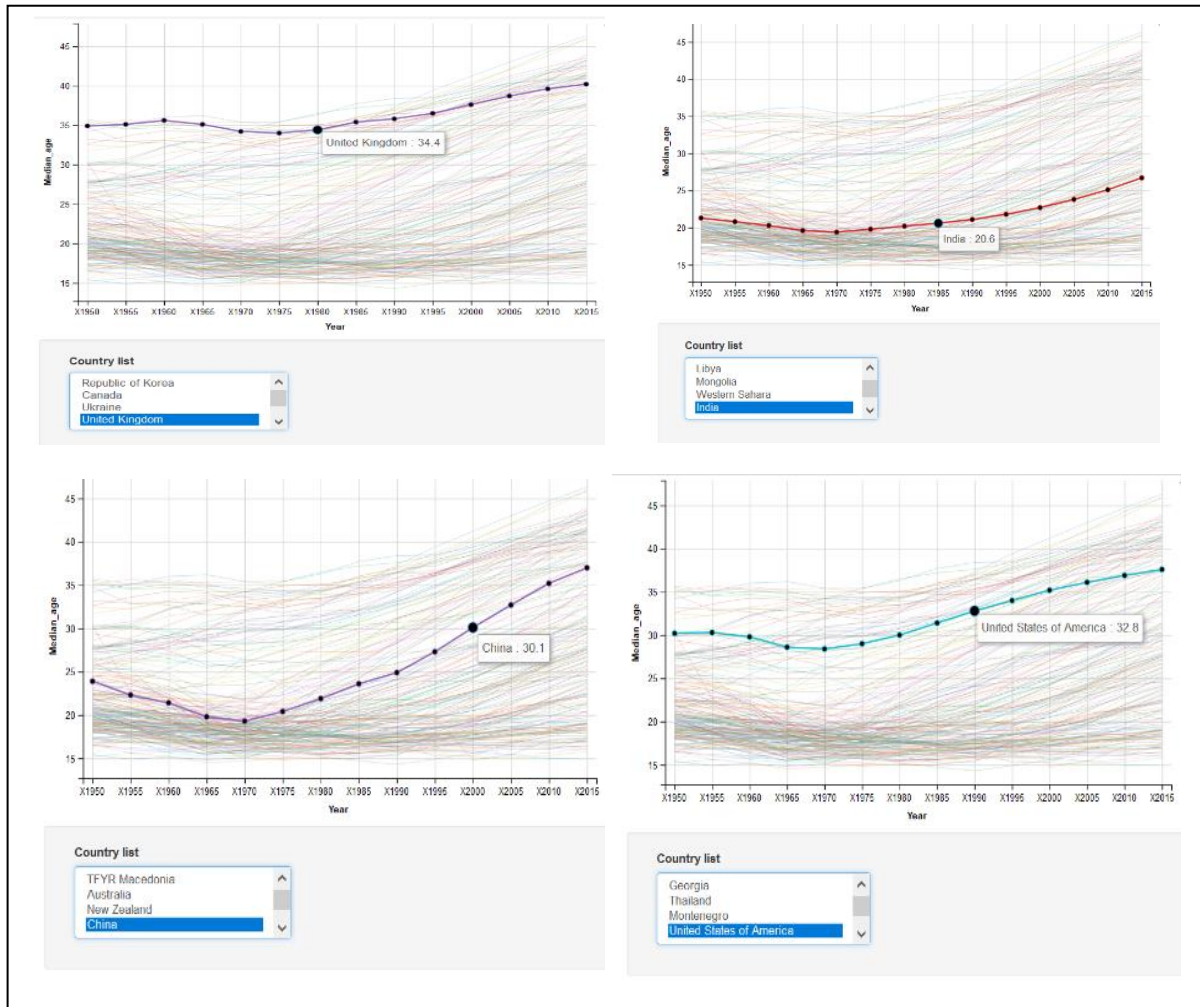
Some interesting findings from this first step:

- The plot clearly shows generally increasing trends of median ages throughout the world.
- The median age is increasing for all the four countries but what is interesting here is that the median ages in 1950 for UK and USA are around 35 and 30 respectively whereas for China and India they are significantly lower i.e., between 20-25.
- Notice, the dip in China's graph where the median age decreased significantly and has grown from around 20 to 35 since 1970. Clearly, China's strategy to curb its population growth rate seems to be working! But the question arises, what does this shift towards an older population mean for their economy? (Will they grow old before they grow rich?)

2. The next step was creating an interactive plot of the world map to see the general trend across the years of median age of countries.

BLUE - higher median ages
GREEN - lower median ages

Some interesting
- How from 1950 to 2015, the blue hues have increased across the map!
- The only green hues (lower median ages) evident are around the equator in some African and Asian countries and a few South American countries too! (Could being near the equator be somehow related to lower median ages?)
- The population growth rates are also higher for countries in the green hues as obviously their median ages are lower because their fertility rates are higher!
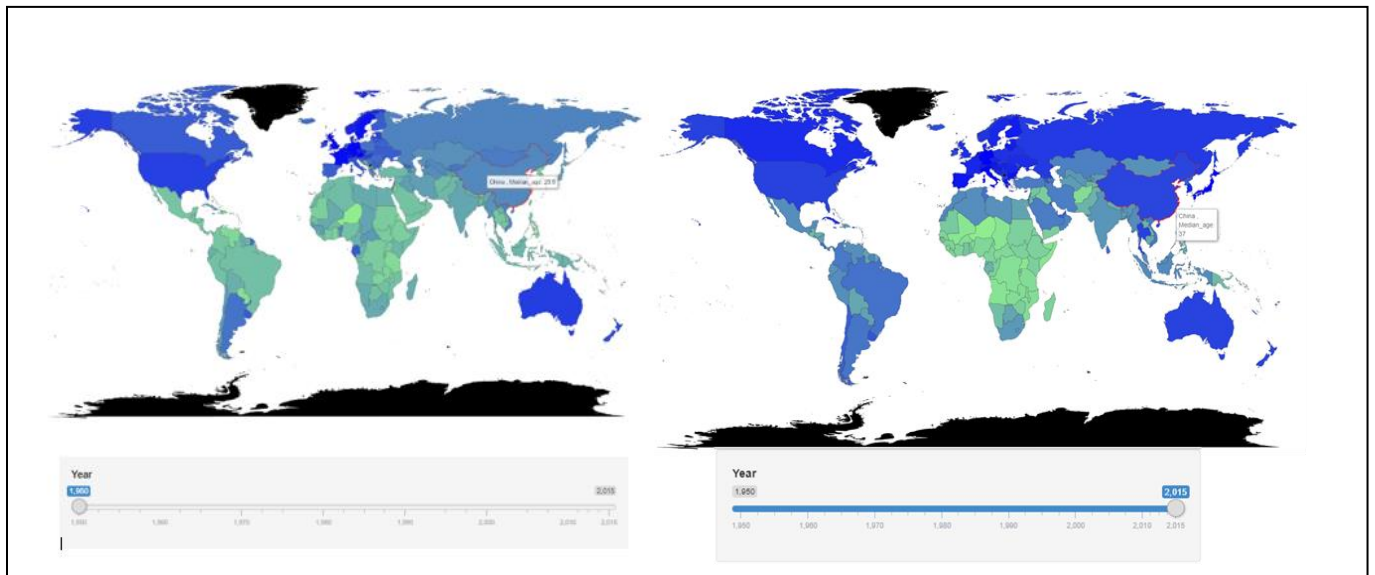
3. Understanding Gross Domestic Product (GDP)

Note that there are many ways and types of GDP calculations, but these were the two of interest to our study as we are trying to see if there is actually a relationship between the median age and the GDP growth rate of the country and since parameters like Consumption values, expenditure values, the national income etc. are all related to the consumers and obviously the expenditure/income will vary from nation to nation based on the ages of say their workforces. Ofcourse, having too many births and young people has its own expenses of providing services like education of the youth, but we're more interested in the impact of old age on the economy for the purpose of this study.

Gross Domestic Product (Expenditure Approach) = C + I + G + (X-M)

where,

C → Consumption i.e., all private consumer spending

G → total government expenditure on employees, schools etc.

I → sum of country's investment on housing etc.

X → Exports from country

M → Imports from country

Gross Domestic Product (Income Approach) = TNI + ST + D + I$_F$

where,

TNI → Total National Income i.e., the sum of all wages, rent, interest, and profits.

ST → Sales tax imposed on the consumers by the government on the sales of goods and services

D → Depreciation i.e., cost allocated to a tangible asset over its useful life

I$_F$ → Net Foreign Factor Income i.e., the difference between the total income that a country's citizens and companies generate in foreign countries, versus the total income foreign citizens and companies generate in that country.

Look at the plot below showing the trend of social expenditure as a percentage of their GDP for countries with high median ages. Notice how their values have increased from 5% to almost above 7% in just 20 years. The slight dip in between also coincides with the dip in median age. So, clearly there's an impact of this changing age mix on a country's GDP.
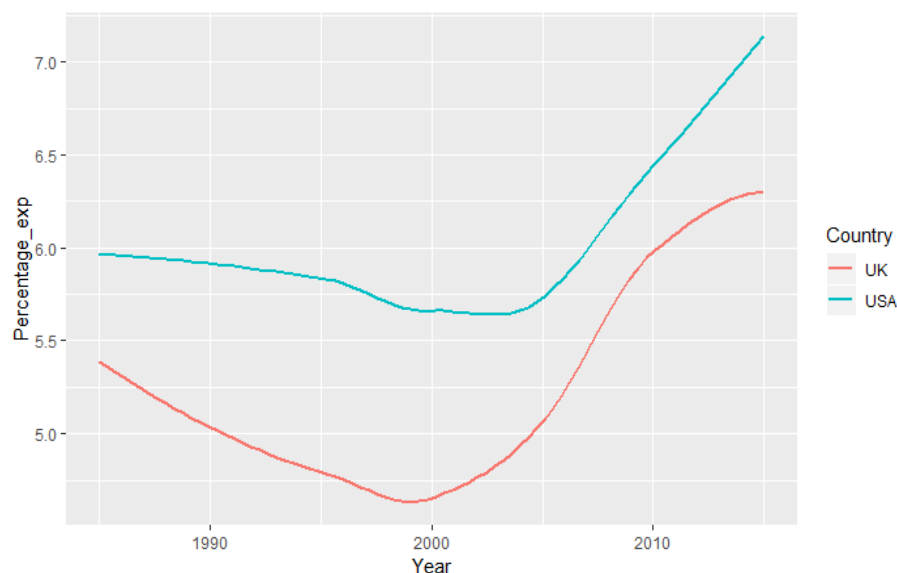
4. Exploring trends in the GDP growth rate of countries

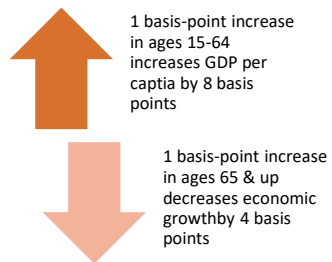Demographic changes can affect GDP growth through several channels:

- Lower growth in population
    - Direct impact - reduced labor input.
    - Indirect impact - individual labor supply, higher tax rates reducing the incentive to work.

- Under the life-cycle hypothesis the consumption smoothing through the lifetime implies people moving from youth to working years to elderly years as shown below:
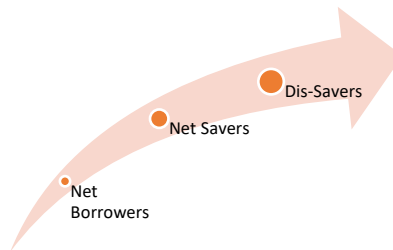
Thus, is the share of elderly in the population rises, aggregate savings would fall, leading to lower investment growth, and, in turn, lower GDP growth. Even the plots shown below, compare the GDP growth rates of developed countries like UK, USA as of 2015 which are around 2% as compared to developing countries like India and China which are around 10%. Of course, developing countries especially like India which is one of the fastest growing economies will have a higher GDP growth rate, but these plots help us realize that there is a downward growth among developed countries and could the age-mix have an affect on this and if yes, how much?
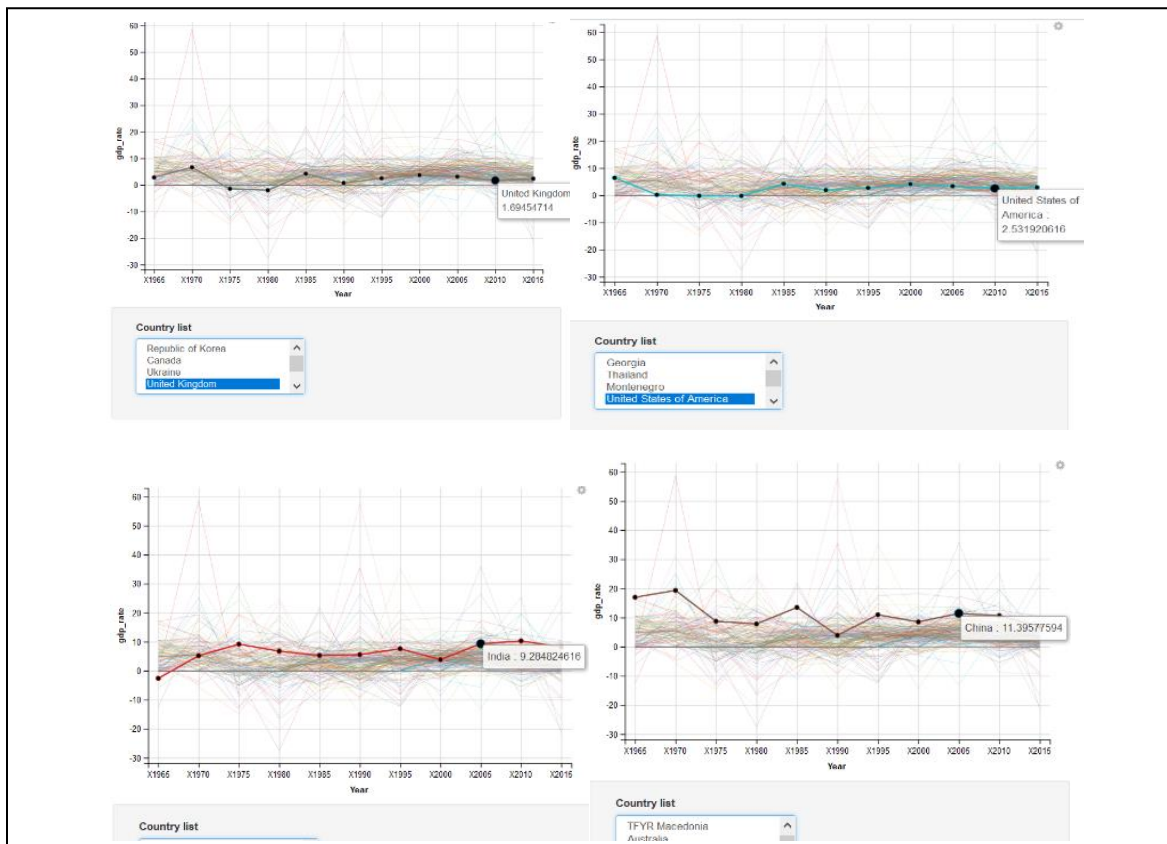
One study presented the following results using a large multi-country panel regression framework:

1 basis-point increase in ages 15-64 increases GDP per captia by 8 basis points

1 basis-point increase in ages 65 & up decreases economic growthby 4 basis points

5. Interactive Plot of the world map showing the GDP growth rates

Interesting takeaways from this plot:

- The brighter the blue hue, higher the growth. Notice the high growth rates of China, some African countries in 1965 and extremely low rate of India!
- In 2015, the hue is reduced overall thus showing what was stated earlier about a general downward growth especially among developed nations. The difference in China is extremely evident as their age has drastically increased in this period.

BLUE – value > 0
GREEN – value < 0
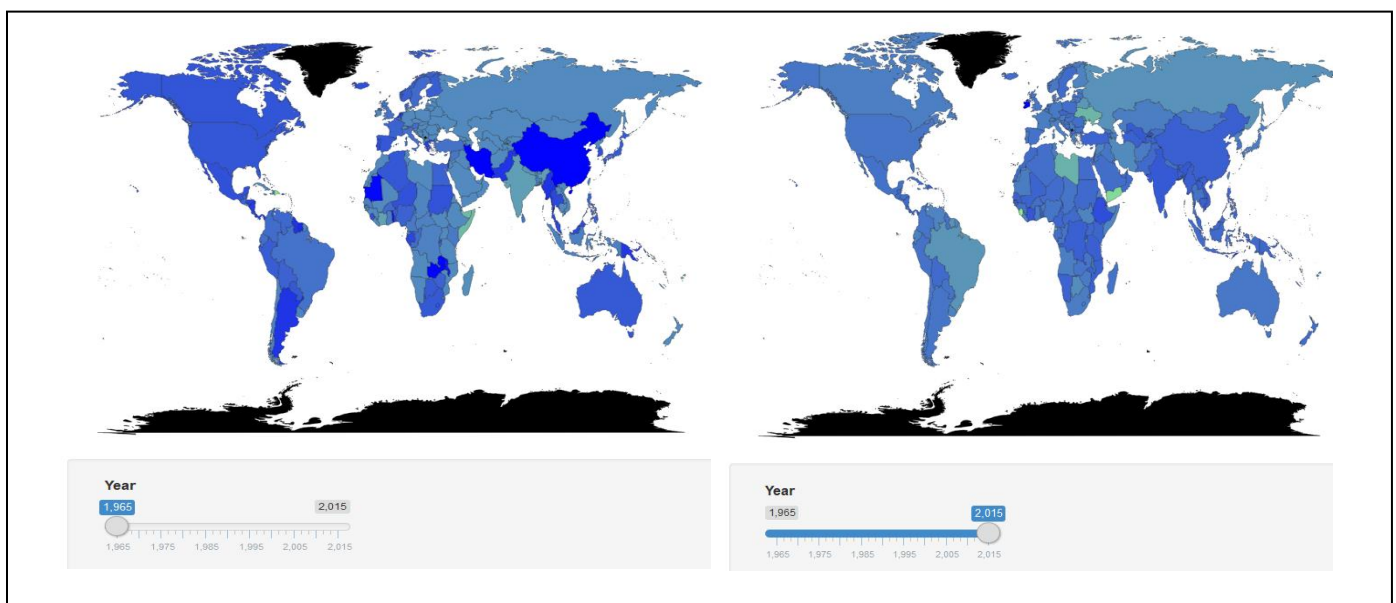
6. Fitting a linear model of GDP growth rate vs, the median age to find correlations

Results & Discussions:

- The negative slope for China clearly shows the negative impact of their increasing median age.
- The positive correlation is higher for India compared to the developed countries as India has an increasing GDP rate and the median age is still low.
- But these values don't help us much in understanding how much impact this demographic factor has on the GDP.
- A snippet of the interactive plot of the world map showing coefficient values is shown below.

Country	Slope
China	-0.2956
Germany	0.2017
India	0.7460
United Kingdom	0.1742
United States of America	0.1517

- Some African countries have a very low value too for various reasons as missing data, too low a median age. This realization is obvious as having higher number of people below working age is also expensive in terms of the services required to educate them etc.
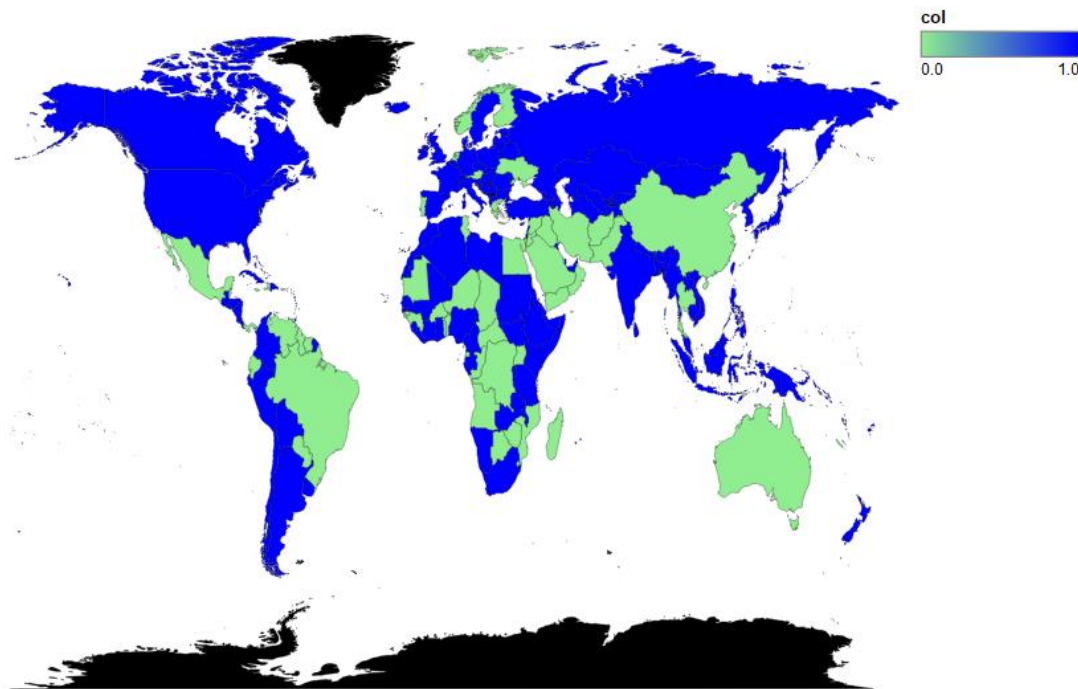

- This model though giving us useful insights, is not enough to conclude and make statements on how much the GDP rate of nations is influenced by the ageing factor. But it definitely proves that there is an impact and an important one

- Some more interesting takeaways and problems from this model:

| Country	Slope
Angola	-4.20422435
Australia	-0.222067301
Finland	-0.172691108
Mexico	-0.333560341

- Australia's median age has increased from 30 – 37 in this period, and a negative correlation shows the negative impact. But, Australia is a developed country and the difference in age is not much between 1965 and 2015 just like other developed countries mentioned earlier such as USA, UK. The correlations are small but positive because the median ages were already high to begin with. There must be other factors affecting the GDP rate more/less than just age which we haven't accounted for.
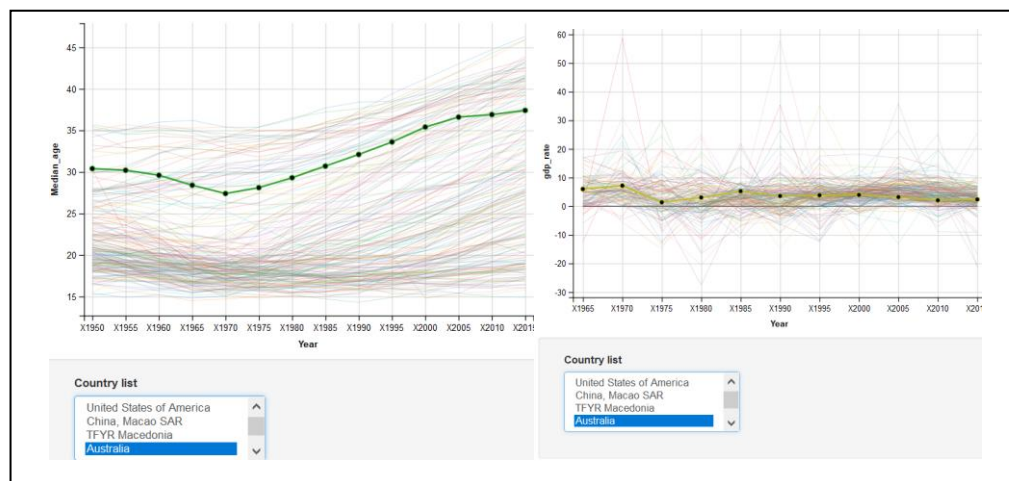
- Angola has a very high negative correlation, as you can see their GDP rate data is not entirely available for many periods and there is a significant fluctuation. Notice their median age is decreasing. Thus, this is adding weight to the realization that a higher low age is also expensive.
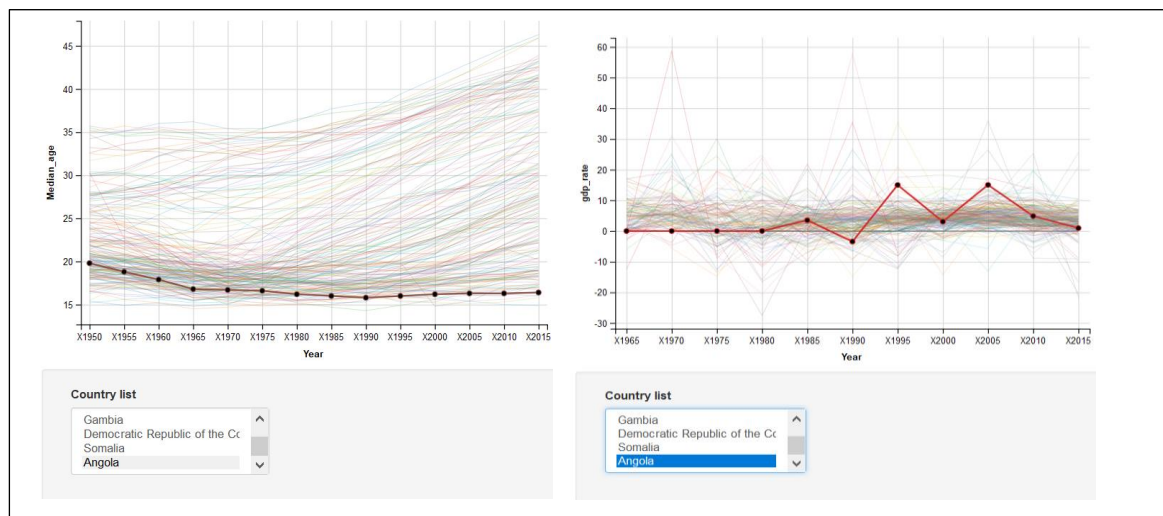
- Finland is also a developed country and the increase in age is also high, from around 27 to 45! Thus, the negative correlation. The affect on GDP is evident!
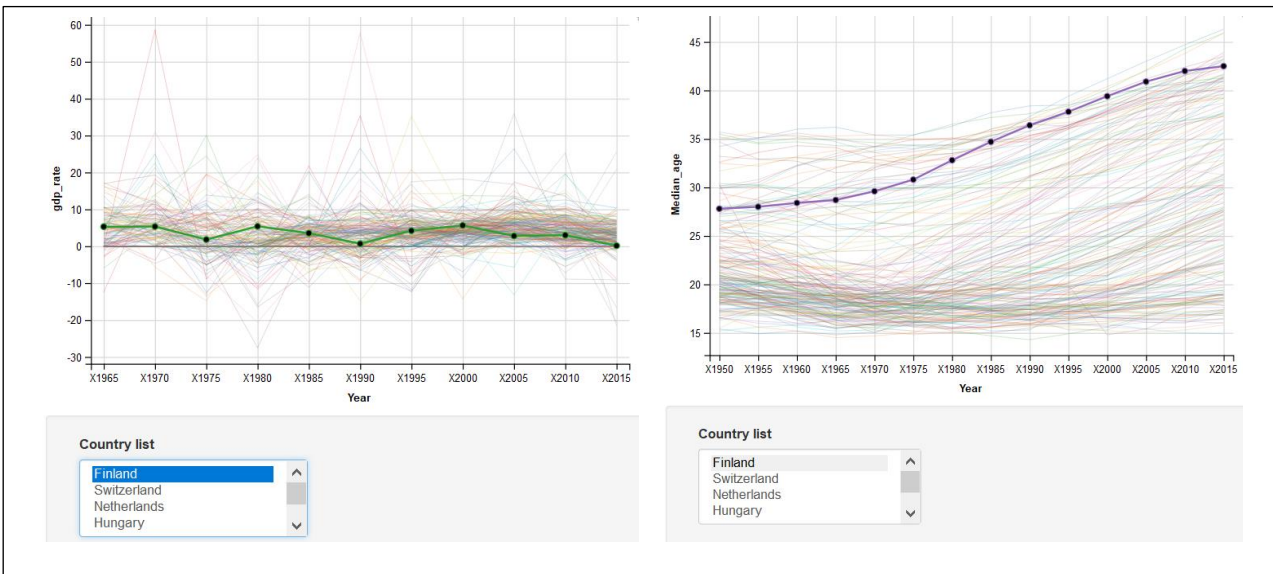
Problems faced and further attempts to solve them:

- Could not quantify the external factors in that time period that could have caused a change in the GDP rate change. E.g., during recession periods when everyone's GDP was decreasing, age could have been steady!
- We tried doing some data analysis to figure out what age could be marked as the limit above which GDP is greatly affected by it. (Did not finish, but the code we wrote is available in the R markdown file)
- Lack of datasets for developing nations i.e., most studies have a narrow geographical coverage as they focus only on advanced OECD economies.

Topics we hoped we would be able to include but couldn't:

- Can immigration and globalization help better manage this uneven age mix?
- Dependency ratios and their impact on economy.

CONCLUSION

The trends of ageing are different across countries. As global linkages have expanded across nations and continue to grow w.r.t to economy, the effects of demographic changes in one country are likely to be transmitted internationally. Policymakers around the world need to understand the implications and adapt to ensure growth in economy.

Most developed countries are a far along in the demographic transition while developing countries are still in the early stages. But, even among these groups of developed and developing countries, there are significant differences. For example, Japan, Korea and some European countries are aging faster than USA. China is aging more rapidly than India among developing countries.

Unless developed countries can offset the impact of an ageing population, there will be shortage of labor which could be solved by increasing productivity or immigration. Countries in the early transition can enhance their growth using the large available work force.

"Life Cycle" changes such as decrease in interest and asset values are a result of an ageing population. Since countries are experiencing changes at different times, additional effect through exchange rates, flow of goods etc. is bound to occur.

However, there is a lack of models to study the complex nature of interactions between demographic and economic factors. It is also difficult to draw inference from historical data due to the paucity of data on large-scale ageing.

Reforms like pension changes, increasing age of retirement may help the developed countries. Immigration might benefit developed countries but losing its educated workforce might weigh heavily on developing nations. Finally, countries need to address the economic and social implications of ageing sooner, especially the ones early in the transition.