The Regional Expressions of Secular Stagnation

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Abstract. This terminology secular stagnation is suggested by Larry Summers in the last decade to demonstrate the globally economic downward trend. Although this standpoint was not paid importance at that time, the unstoppable decrease in world economy of recent years has shown this. Driven by these miscellaneous data, this report aims to search for evidence that can argue the secular stagnation. Thereby, we first analyse and select the objective tabular data from 1970s to 2010s covering all countries to apply the multiple linear regression model. Then the statistical theory is used for both preliminary measurement and subsequent regression diagnostics, also for the estimation method. In data processing, this paper explores the relationship between economic slow-down rate and (the logarithm of) affluence level with the random forest logarithm to find the threshold. Through the data visualization, the economic trend during the corresponding objective period can be observed intuitively. Finally, in the extension of the slow-down rate, we try to excavate the deep interactive terms among all countries. By the Solow growth model, it can be concluded that the gap between developing countries and developed countries is narrower due to the low original capital of poor countries. This phenomenon is also known as the catch-up effect. This report conducts the slow-down rate to verify the secular stagnation and meanwhile provides evidence for the relationship between slow-down and affluence levels.

1. Introduction

1.1. Background
It seems that the growth rate of world economy has already gradually slowed down before the Covid-19 pandemic, which is suggested by Jacobs et al. [1]. It is noteworthy that this phenomenon is more concerning in developed countries, as majority of high-income countries are stuck in a trap that there is an insufficient demand to boost their economies. Moreover, as Younis and Nafla [2] suppose that the monetary policies of these countries are facing invalid dangers, possibly causing financial instability and adverse effects on economic development. Therefore, people started to take notice of the reliability of a controversial hypothesis called ‘secular stagnation’. In 1938, six years after Great Depression, Alvin Hansen [3], a chair professor at Harvard University, coined a new nation ‘secular stagnation’, which means that a diminishing growth rate could persist in long run after a great recession due to a lack of technological innovation and a slow population growth. However, his argument was subsequently proved wrong when the World War 2 started, a significant
increase in spending on military defences, and competitions on technology and weapons among
countries largely facilitated an economic boom.
His theory was forgotten until 2013, the former Chief Economist of the World Bank Lawrence
Summers (2013) re-introduced it after Global Financial Crisis, bringing it back to the public eye again.
In the speech given by Summers [4] at International Monetary Fund (IMF), he suggested that the
recovery from 2008 Financial crisis was the slowest in history even with such a low interest rates bound.
The rise in saving, the slowdown of population and technology constituted an insufficient demand,
which then led to secular stagnation.
In responding to this concept, it should be found out that whether the secular stagnation exists or not,
and the belief that those richer countries are suffering severer secular stagnation than poorer countries.

1.2. Objective
The main objective of this research about secular stagnation is to find whether there are evidences to
support this controversial hypothesis. In this paper, the measurement of affluence level in all countries
will be evaluated and the investigation about the relevance between countries’ wealth extent and growth
slowdown rate will be demonstrated to visualize the secular stagnation. In the first stage, the
comparisons between productivity, GDP and GDP per capital give advice on which one is a more
suitable parameter to quantify the wealthy degree. In the second stage, a scatterplot is generated to
indicate the relationship between the slow down rate and countries’ affluence level. By observing the
tendency of the diagram, the secular stagnation seems to be substantiated. The terminal stage is bent on
excavating deeper into the causes of the distribution of slow-down rate and explaining some internal
connections through theories. Furthermore, a reflection about limitations is discussed, following is the
conclusion.

2. Literature
This section illustrated other economists’ perspectives about secular stagnation, incorporating the critics
from Joseph Stiglitz, and the insufficient evidence from Summers’ research noted by Roger Farmer. In
addition, brief views by Paul Krugman and The Economists are placed as well.
The former Chief Economist of the World Bank Joseph Stiglitz [5] countered the ideology of secular
stagnation by noting that the effective fiscal stimulus can fully offset this dire prediction. He argued
that the languishment of the economy is not caused by the economy itself, but the noneffective and
insufficient fiscal stimulus policy. He gave an example of a large fiscal stimulus in December 2017 and
January 2018 and said that the effectiveness of that would have been enlarged a decade earlier with a
high unemployment rate. He also asserted that whether the economic growth rate in the future can be as
fast as that in the past, it depends on the rate of technology development and proper intervention by
government.
According to the debate between Summers and Stiglitz [6], the Professor of Economics at the
University of Warwick Roger Farmer [7] gave his own opinion about secular stagnation. He claimed
that both Lawrence Summer’s and Joseph Stiglitz’s theories are expected to be re-examined by new
economic model, and he asserted that Summer did not illustrate a fully well-structured equilibrium
model that backed his suggestion. However, he agreed with Summer’s advocacy that free economy
may be failed to adjust back to full employment after a significant shrink of economy. His internally
coherent theory explained the reason of the secular stagnation, which incorporated Keynesian
economics. The high permanent unemployment is irrelevant with sticky price, but a missing essence of
markets.
On top of that, Paul Krugman [8] pointed out that the root of this problem is that whether the policy
maker can stimulate people to spend money when they lose the faith of the economy. While Eggers,
Ellison and Lee [9] criticized that the theory of secular stagnation ignored the underly improvement of
technology and it is always to be revised after recessions, and soon it is to be proved false during a
boom in economy.
3. Data and Theory

3.1. Sources
According to Probst [4], the researcher in economic history, the OECD projections foresee the growth in all advanced economies is much slower than that a few months ago. The following Figure 1 display the predications from last May to the latest outlook, with the red arrows indicating the most dramatic downward.

|          | 2017 | 2018 | 2019 |
|----------|------|------|------|
| World    | 3.7  | 3.8  | 3.9  |
| Australia| 2.3  | 2.9  | 3.0  |
| Canada   | 3.0  | 2.1  | 2.2  |
| Euro area| 2.6  | 2.2  | 2.1  |
| Germany  | 2.5  | 2.1  | 2.1  |
| France   | 2.3  | 1.9  | 1.9  |
| Italy    | 1.6  | 1.4  | 1.1  |
| Japan    | 1.7  | 1.2  | 1.2  |
| Korea    | 3.1  | 3.0  | 3.0  |
| United Kingdom | 1.8 | 1.4 | 1.3 |
| United States | 2.3 | 2.9 | 2.8 |

Figure 1. Economic changes in the world and some developed countries in recent years [4]

Additionally, economic growth rates of developed countries have been slowed down in recent years. The most representative one is American economy, whose actual economic growth has been below the potential economic growth rate since global financial crisis [10]. Meanwhile, monetary policy becomes an invalid policy, as most interest rates of developed countries are closed to zero, it is no longer an effective method in terms of stimulating demand [11]. The statistics in Figure 2 demonstrate the business cycle of USA, and in Figure 3 the interest rates of developed countries.

Figure 2. The economic growth rate of the USA [10]
Figure 3. Interest rates of developed countries [11]

Lawrence Summer’s research made a comparison about the difference between actual growth and economic potential trend within three economies, pointing out that the estimate of GDP potential growth of America in Figure 4 [12] was lowering down after global financial crisis while the disparity between the predict lines and actual growth has been increased. Additionally, the example of Japan and EU economy in Figure 5 and Figure 6 [12] showed that their economy went to a trap as the old monetary policies were unable to stimulate the demand any longer.
Figure 4. Actual and potential GDP from 2007 to 2014 [12]

Figure 5. Forecast and reality of Japan and Europe [12]

Figure 6. Actual and potential GDP in developed countries [12]
3.2. Theory derivatives

A. The R language theory such as multiple linear regression analysis and diagnostics is used.
B. The statistical theory is used in three sessions, to make comparisons among measurements in data processing; in the form of OLS method in estimation part; in the form of Gauss-Markov theory to judge whether the error is reasonable.
C. The approach of random forest is used for the appearance of slow down rate.
D. The Solow growth model and Summer hypothesis are applied to the extension of research, including catch-up effect and leapfrogging effect.

3.3. Data Processing

3.3.1. GDP per capital and productivity, which is a better measure? Since either GDP per capital or productivity will be used to measure the slow down rate in the final stage, this research begins with finding out the relationship between GDP per capital and time, as well as productivity and time, respectively. Therefore, the multiple lineal regression is applied to these two relationships.

In both experiments, three dummy variables are uniformly constructed, namely $D_1, D_2, D_3$, which represent for progressive levels of affluence, to divide all countries in the world into three parts. Next, breakdown countries secondarily in the light of the data from World Bank [13]. Additionally, $\varepsilon_i$ is used to describe the interactive terms that has impacts on GDP per capital or productivity.

Firstly, for GDP per capital, we have the following regression function:

$$GDP\ per\ capital_i = \alpha + \beta x_i + \gamma_1 D_1 + \gamma_2 D_2 + \gamma_3 D_3 + \varepsilon_i$$

where $i$ is serial numbers of countries, $i=1,2,\ldots,182$

- $x$ is year,
- $\alpha$ is the intercept,
- $\beta$ is the slope,
- $\gamma_1, \gamma_2, \gamma_3$ are coefficients of dummy variables

It is demonstrated by Dynan and Sheiner [14] that the expression for GDP can be conducted by expenditure-side approach as

GDP = private consumption + gross investment + government investment + government spending + (exports - imports).

According to the formula of GDP calculation, select the following data respectively,

- **Real consumption of households and government** $(ccon)$, which means the personal consumption of households and the consumption of government;
- **Capital stock at Constant 2011 National Prices** $(rnna)$, which means gross growth in investment and government investment, "gross" refers to the fact that GDP measures production and does not consider the various uses of the product. Production can be consumed, invested in fixed assets or inventories, or used to replace depreciated fixed assets [15];
- **Price level of exports** $(pl-x)$, **Price level of imports** $(pl-m)$. Since the price level of the market is affected by the rate of inflation, our exports and imports are measured by the price level.

Then the GDP per capital is

$$\frac{GDP}{population} = \frac{ccon + rnna + plx - plm}{population}$$

Use R to do the regression analysis, the adjusted-$R^2$ can be worked out to quantify the relationship between GDP per capital and time as in Figure 7.
Besides, the conformity of total GDP is also be studied. However, as the Figure 8 shows below, it seems to be a subordinate choice.

Secondly, for productivity, the regression function is:

\[ \text{productivity}_i = \alpha + \beta x_i + \gamma_1 D_{1i} + \gamma_2 D_{2i} + \gamma_3 D_{3i} + \epsilon_i \]

where \( i \) is serial numbers of countries, \( i=1,2,\ldots,182 \)
\( x \) is year,
\( \alpha \) is the intercept,
\( \beta \) is the slope,
\( \gamma_1, \gamma_2, \gamma_3 \) are coefficients of dummy variables

Scheryer and Pilat [16] pointed out that the productivity can be measured by gross output, that is, the relation is presented as a production function \( H \) with gross output \( Q \),

\[ Q = H (A, K, L, M) \]

where \( L \) is labor input,
\( K \) is capital input,
\( M \) is intermediate input,
\( A \) is a parameter of technical change

Here use emp*avh in excel to stand for the expression of productivity. That is,

Productivity= Number of persons engaged (in millions) * Average annual hours worked by persons engaged

By R, the adjusted-\( R^2 \) can be observed in Figure 9.
In Figures 7, 8, 9, R language is used to seek variables linked to the multiple linear regression. For instance, the list of residuals enumerates 5 numbers in the form of boxplot, the quartiles are introduced to describe the median \( Q_2 \), the median of the lowest half \( Q_1 \), and the median of the highest half \( Q_3 \), also with the minimum and the maximum. Likewise, the tabulation of coefficients covers four characteristics of both the intercept and the explanatory variables. ‘Estimate’ means the estimated value calculated by R, the second column represents for the standard error, ‘t value’ is the test statistic for t-test, the last column is the probability of rejection in hypothesis test. Below are the significance codes, which help to judge what extent of evidence should be rejected. Finally, the multiple R-squared is the initial value and the adjusted R-squared is corrected value. The p-value can also be viewed as the test statistic.

\( R^2 \) correlation system test method is used to judge the fitting degree of the regression equation. The value of \( R^2 \) is between 0 and 1, and the closer to 1, the better the fitting degree is. We want to assess how useful the model is in explaining the data. This can be assessed by the value of adjusted-\( R^2 \).

Let SSR denote the regression sum of squares, which measures how much of the variation in the y values is explained by the regression; SST denote the total sum of squares, which measures the total amount of variation in the y values. The proportion of SST explained by SSR is \( R^2 \).

\[
SST = \sum_{i=1}^{n} (y_i - \bar{y})^2
\]

\[
SSR = \sum_{i=1}^{n} (\hat{y}_i - \bar{y})^2
\]

\[
R^2 = \frac{SSR}{SST}
\]

\[0 \leq R^2 \leq 1\]

By looking at the data result of the model, it can be observed that the p-value is less than 0.01. Therefore, it is known from t-test that the independent variable X is very significant in Y, and it is judged from F-test that the independent variable of the whole model is very significant. Meanwhile, \( R^2=0.4001 \) in Figure 7 means that the independent variable and the dependent variable are highly correlated. According to the R output in Figure 8, on the whole, independent variable has a significant correlation with Y, but \( R^2=0.05083 \). Therefore, it is judged that the independent variable and the dependent variable have a low correlation and a low goodness of fit. Hence, in these experiments, it can be obtained that the GDP per capital is a better measure as its adjusted-\( R^2 \) is closer to 1.
3.3.2. The scatterplot of slow down rate.

Linear regression analysis

Next stage, it is necessary to work out the trend of slow down rate to visualise the secular stagnation by studying the relationship between slow down rate and affluence level. Firstly, a scatterplot should be drawn to explore the distribution of slow down rate in different countries and the relationship between slow down rate and the affluence level. Choose GDP per capita as a measure for these two variables according to the last stage, because it is more appropriate than the productivity.

For the y-axis, that is, the slow down rate, which is defined to be equal to the average growth rate from 1994 to 2017 minus the average growth rate from 1970 to 1993. That is,

\[
\text{Slow down rate} = \frac{\text{average growth rate from 1994 to 2017}}{\text{average growth rate from 1970 to 1993}}
\]

If the slope is positive, this means that there exists an acceleration in the economic growth, while the negative value means the downward economic growth rate. However, if the GDP per capital is used as x-axis, there will be a strong influential outlier, compelling all scatters clustering to the left. Hence, a transformation is conducted by adding logarithm to the GDP per capital. The influential observation is weakened in this case. Likewise, rank the values of GDP per capital from the smallest to the largest through the time period 1983-1993, where the assumed slow-down has not happened. Therefore, a scatterplot can be drawn as shown in Figure 10 to indicate the distribution of slow-down rate in all countries.

![Figure 10. The scatterplot and fitted line of slow-down rate versus the logarithm of GDP per capita](image)

By R, the scatterplot is runed out. It can be obviously observed that there are three outliers, all should be checked. One is on the right-hand-side, this country has the largest GDP but its slow down rate is negative. It can be found from the data table that this country is Qatar, which is an oil produced country [16]. Thus, its export level is much higher than other countries, explaining the high GDP value. Another two outliers are outside the interval [-0.1, 0.1], they are Georgia and Equatorial Guinea, the former [17] accelerated the economic development in the 1990s and the later [18] implemented the economic restructuring in 1987.

From the scatterplot, the tendency can be roughly observed. Next, a fitted linear regression can be worked out, which appears to imply the secular stagnation as its slope is negative. However, the practical meaning of this graph may be illogical because of the constant drop. This tendency derives from the laws of the real world. Therefore, there exist a threshold point that divide the tendency of slow down rate into two parts, with a gradient descent.

Data transformation

To find the threshold, position it relative to the middle of the scatterplot at first according to the distribution of scatters, i.e., within the interval (-5, -4). By the approach of random forest from Prasetiyowati, Maulidevi and Surendro [19], traverse all points in this interval to find a point where
the residual sum of squares is the smallest among them. Hence, after calculating all possible points, the country code with the smallest SSR is CHN. Next, take the means of the two segments, one has the logarithm of GDP per capital smaller than CHN and the other has the logarithm of GDP per capital larger than CHN. Then, a transformed fitted line plot with a gradient decent at the threshold can be displayed in Figure 11. The average value of the former segment is 0.03477754 and the average value of the later segment is -0.007733709.

![Fitted line plot](image)

**Figure 11.** The transformed slow-down rate

It can be summarised from Figure 10 that the world undertakes the economic downward pressure as the global economy grows steadily. Moreover, there’s a relationship between slow down rate and affluence level, a richer country suffers from a more severe economic downward. Since the slow down rate is below zero, it can be concluded that the world economy is experiencing **secular stagnation**.

### 3.3.3. Regression diagnostics

To examine the fitness of the linear regression, run R and we obtain four regression diagnostic diagrams as shown in Figure 12.

![Regression diagnostic diagrams](image)

**Figure 12.** The regression diagnostic diagrams
From Figure 12, the two graphs on the left-hand side are residuals and fitting diagrams, they reveal the relationship between fitted values and true values by residuals and standardized residuals. Both suggest that the points are reasonably close to a straight line, with the scatters evenly distributed on both sides of the horizontal line. Additionally, the Normal Q-Q figure is used to judge whether the residuals satisfy normal distribution. It shows three outliers and a non-distinct tail that away from the straight line, but most of points are within the interval [-1.96, 1.96]. However, the problem is that the points don’t fall on the line at an angle of 45 degrees. This will be explained later. Finally, the residual versus leverage diagram is displayed. In this Scale-Location graph, several influential observations exist, meaning that they make strong influence on the regression.

![Normal Q-Q Plot](image)

**Figure 13.** The normal Q-Q plot

Figure 13 is the normal Q-Q plot of the transformed tendency, the degree of the slope of the straight line is about $45^0$, which is more appropriate than before despite of some points do not fall on the line. To sum up, the fitted line is reasonable to assumption although some deviations exist.

### 3.4. Advantages and improvements

#### 3.4.1. Advantages

- The multiple linear regression model is used to conduct regression analysis on GDP per capital and productivity, and the optimal measurement is selected to make the results more reliable.
- Dummy variables are introduced in the experiment to divide countries into three partitions, so that the data can improve the accuracy of the model, also it can reflect the relationship between the affluence level and slow down rate more accurately.
- The least square method is used in curve fitting of slow-down, which can make the parameters fitting result better.

#### 3.4.2. Improvements

The strategies for improvements are based on the potential threatens of the data analysis. In this study, firstly, the limited data in data processing will affect the final results to some extent. One is that the data of GDP in target countries is incomplete in the origination year, which gives rise to an inaccuracy in the process of data analysis. Considering the necessity to analyse the GDP of developed countries, developing countries and poor countries in the same time period to keep conformity, chose from 1983 to 1993, which is before the gradient decent and relatively complete in data. Another limitation is that, when filtrating the data, there exist two countries (CUW and SXM) that only have the data from 2005 to 2017. They are deleted as they break the consistency of the selected data. However, some other
countries also have missing data when calculating the GDP, although these are much fewer than that in two countries. For example, data are not available for some years in selected countries in the time period 1983-1993, some countries only have data from 1990 to 1993. Thus, the GDP is ultimately measured by its definition, that is, GDP = Private Consumption + Gross Investment + Government Investment + Government Spending + (Exports - Imports). The indispensable problem is that the time periods from 1983 to 1993 or 1990 to 1993 is too short, so it may be one-sided to judge the opulence degree of a country based on the data within 10 years, let alone the economic changes.

Secondly, the optimality of variables in the regression model is noncommittally remaining a problem. From the perspective of classification, the developed and developing countries can also be divided by other categories, such as exports, technology and people's living standards, etc., leading to enormous different consequences. From the perspective of interactive terms, since the price level of exports and price level of imports are used in the first stage, the price level may be affected by inflation. Adversely, this term is not added to the model as the interactive term is set to be default 0. There is another variable in the excel tabulation needed to be noticed---the purchasing power parity (PPP). If convert the expression of GDP per capital into the one that with the variable purchasing power parity (PPP), it may be far from the actual result due to the variability of theoretical exchange rate in the calculation. The only thing that ought to be ensured is that each country measures the GDP in the same way with the same monetary unit.

Thirdly, the regression diagnostics exist some defects inevitably. In Residuals vs Fitted diagram, which is a scatterplot of residuals-fitted values (Y-X) for residual analysis. This graph can be used to detect nonlinearity, unequal error variances, and outliers. In the Figure 12, the distribution is basically uniform on both sides of the line, but the scatters seem to be inclined to a central distribution and the line is slightly skew to a horizontal straight line. The error distribution also does not conform to the Gauss-Markov Condition. Similarly, the Y-axis of the scale-location diagram is the extraction of the Y-axis of Residuals vs Fitted diagram and both have the same X-axis. For the scale-location diagram, it shows whether the residuals are uniformly distributed along the range of predictors to check the equivalence of variance hypothesis. Theoretically, there would be a horizontal straight line with evenly distributed data, but in reality, it seems not to be a horizontal line with the far left and right points deviate from it.

The Normal Q-Q plot represents for the normality of the univariate distribution of the data set. If the data is normally distributed, the points will fall on the 45-degree reference line. Otherwise, the points will deviate from the reference line. But in fact, the 45-degree sloped line in the model does not start at the origin and the data does not fall completely in line, with a tail divorced from the precedent trajectory. Therefore, the data does not fit the Y=X line, and the error cannot follow a perfectly normal distribution as well.

For the Residuals vs Leverage diagram, which can check the outliers of the regression model. It can also be used to detect the heteroscedasticity and nonlinearity of data set. The Figure 12 witnesses that some points are too far away from the regression line, which contributes to the imprecision and unpredictability of the model.

Generally, the problems in the regression diagnostics stem from the precedent limited data and the variables that may not be correct. Instead of deleting or keeping the missing values, maybe the preferred method is to do missing value processing by the multiple imputation method, that is, to seek for alternative values. Furthermore, to upgrade the accuracy of the regression model, some algorithm conversion can be used and the variable adjustments can also be applied. Finally, outliers may sometimes affect the result severely, this could be amended by some mathematical transformations.

4. Estimation and results

4.1. Estimation method

First, it should be checked that whether the residuals have a normal distribution, through drawing a histogram of residuals, this consumption can be verified as in Figure 14.
Since the multiple linear regression is used before, naturally the method of Least Square (OLS) is applied to examine how well the model is. Need to minimize the sum of squares of the difference between the true values and the fitted values.

$$\min_{\alpha, \beta} \sum (y_i - \alpha - \beta x_i - m(x_i))^2$$

where $m(x_i)$ represents for the dummy variables term and the interactive term. This gives the estimates $\hat{\alpha}, \hat{\beta}$, where $\hat{\alpha} = \bar{y} - \hat{\beta} \bar{x}$ and $\hat{\beta} = \frac{\sum (x_i - \bar{x})(y_i - \bar{y})}{\sum (x_i - \bar{x})^2} = \frac{\text{Cov}(x_i, y_i)}{\text{Var}(x_i)}$

As it is tested before, the estimates are as following (Figure 15):

```
Residuals:
Min 1Q Median 3Q Max
-0.11081 -0.03361 -0.000621 0.01894 0.92518

Coefficients: (1 not defined because of singularities)
(Intercept) -2.565e+00 6.900e-02 38.345 <2e-16 ***
y 1.309e-03 3.364e-05 38.903 <2e-16 ***
D1 NA NA NA NA
D2 -1.287e-02 1.448e-03 -8.891 <2e-16 ***
D3 8.899e-02 1.492e-03 59.009 <2e-16 ***
---
Signif. codes: 0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 0.0608 on 10000 degrees of freedom
(2371 observations deleted due to missingness)
Multiple R-squared: 0.4001, Adjusted R-squared: 0.4001
F-statistic: 2215 on 3 and 10001 DF, p-value: < 2.2e-16
```

Figure 15. The R output for the regression of GDP per capital

The missing values in $D_1$ is caused by the fewer number in the richest countries.
The coefficient shows that there is a relation between the year and GDP per capital, also the p-value indicates the strong evidence. The standard error deviation is within a reasonable range. Have $R^2 = 40.01\%$, meaning that the regression explains 0.01% of the variation in the data. This is not a low percentage, suggesting a useful regression relationship and the relation is not causal.

4.2. The relationship between slow down rate and affluence levels

After the verification, the fitted line is a piecewise function and there is a continuous linear relationship with a discrete shift between the slow down rate and affluence level. It has an overall decrease in the slow down rate, which implies the affluence level of countries is in direct proportion to the slow down rate. Since the slow down rate of almost all countries is negative without the logarithm, it comes out that the world is confronted with secular stagnation.

However, what the interactive nexuses between poorer countries and richer countries or of slow down at similar rates are needed to be explained, although the hypothesis of the subject has been verified. A
correlative terminology is the Solow growth model, which demonstrates three factors -- technology, capital accumulation and labour force that drive economic growth. It implies that the less capital in poor countries to start with can narrow the gap between rich and poor countries as each additional unit of capital is inclined to yield higher return than in a richer country [20]. This is also the concept of catch-up growth. Hence, the gradient decent can be explained by this model because the difference of slow down rate on both sides of the threshold is stable and will not become wider. Meanwhile, it is suggested by Steinmueller [21] that the development strategy of ‘leapfrogging’ is supported by information and communication technologies (ICTs), it also narrows the gaps in industrialized and developing countries. The leapfrogging indicates that small and incremental innovations can sustain the leading position of a dominant enterprise [22].

Recently, as the Summers hypothesis says, the productivity improvement for agriculture and manufacturing are close to saturation [23]. Therefore, the underlying rate of technology progress has slowed down. More productivity improvements are needed in service sector for which may require large ICT developments. Since a large amount of technology transfer comes through FDI (foreign direct investment), by searching for the data source traversing all countries from 1970 to 2019, it can be seen in Figure 16 [24] that the countries with high FDI tend to have the similar slow-down rate. But the countries with low FDI do not follow this trait owing to several special countries.

![Figure 16. FDI in specific countries [19]](image)

### 5. Conclusion

This report aims to study the relationship between the slow down rate of economy and affluence level among all countries in the world to explore the forward or backward evidence for secular stagnation. At the beginning, GDP and productivity are compared to choose a better measure for economy, also namely affluence level. After some calculations and comparisons, GDP per capital is more suitable to measure the level of economic development of a country, whether from a theoretical perspective or from specific data analysis. It can be thought of as a "best fit" unit of measure to argue the tendency of economy. Next, the tendency of slow down rate is worked out through seeking the relationship between slow down rate and affluence level. The negative value of slow down rate implies the secular stagnation. Finally, to examine the accuracy of multiple linear regression model and fitted line plot, the regression diagnostics and estimation method are used. The result comes out to be reasonable and appropriate but lack of precision.

However, the problem is that, the absence of data on GDP, the Capital Stock at Constant 2011 National Prices (RNNA), Price Level of Exports (PL-X), and Price Level of Imports (PL-M), which
are consistent with the formula of GDP calculation, resulting in an unsatisfactory regression model. Although the model has been analysed and the direction of improvement has been put forward, the problem remains to exist. When using OLS method to test the model, the error of the data was within a reasonable range, so it can be concluded that the world is faced with secular stagnation.

After providing the evidence for secular stagnation of Larry Summers’s suggestion, it can be more deeply realized that when the economy reaches to a certain point, the downward tendency may inevitably always exist. Thus, the root of stagnation needs to be found to solve this global problem more effectively. It is definitely a challenge to find a way of constant growth in economy within a global scope.

6. References

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7. Appendix

library(readxl)
pwt92 <- read_excel("R prologue/pwt92.xlsx", 
    sheet = "GDP")
View(pwt92)

G <- pwt92$'GDP per capital'
Y <- pwt92$'year'
D1 <- pwt92$'D1(poorest)'
D2 <- pwt92$'D2(middle)'
D3 <- pwt92$'D3(richest)'
states <- as.data.frame(state.x77[c("G", "Y", "D1","D2","D3")])
corr(states)
fit <- lm(G ~ Y + D1 + D2 + D3, data=states)
summary(fit)

library(readxl)
pwt91 <- read_excel("R prologue/pwt91.xlsx", 
    sheet = "productivity")
View(pwt91)
L <- pwt91$laborinput'
Y <- pwt91$year'
D1 <- pwt91$D1(poorest)'
D2 <- pwt91$D2(middle)'
D3 <- pwt91$D3(richest)'
states <- as.data.frame(state.x77[c("L", "Y", "D1", "D2", "D3")])
cor(states)
fit <- lm(L ~ Y + D1 + D2 + D3, data=states)
summary(fit)

library(readxl)
slow_down_rate <- read_excel("R prologue/slow down rate.xlsx")
View(slow_down_rate)
S <- slow_down_rate$slow down rate'
G <- slow_down_rate$GDP per capital'
states <- as.data.frame(state.x77[c("S", "G")])
fitted(fit)
residuals(fit)
fit <- lm(S ~ G, data=states)
par(mfrow=c(2,2))
plot(fit)
plot(G,S,Glim=c(2200,500000),Slim=c(-1,1))
abline(fit,col="red")
res <- residuals(fit)
hist(res, main = paste("Histogram of residuals"), breaks = 8,
     xlab = "Residuals", xlim = range(-0.2,0.2), col="purple")
library(nortest)
ad.test(res)
qqnorm(res, col="blue")
qqline(res, col="red")
plot(G, S, col="blue", pch=19, main = paste("Fitted line plot"),
     xlab = "GDP per capital", ylab="slow down rate")
abline(fit, col="red")
library(randomForest)
randomForest(S~G, data=states,importance=TRUE, ntree=180,na.rm=TRUE)