The solow swan model of economic growth

1. 0 Purpose

Examine aspects of the Solow-Swan model of economic growth and identify whether capital accumulation has been the cause for growth in the cases of South Korea and Australia.

2. 0 The Solow-Swan Model in brief

The model shows how growth in capital stock (KM) and labour (L) affect economic growth (Y). It assumes that there is diminishing marginal returns for labour and capital considered separately as inputs and constant returns to scale when taken together.

Mathematically, this is expressed as:

$Y = AK^{\alpha} L^{1-\alpha}$ (from Cobb-Douglas Production function, where Y= National Income, K= Capital, L= Labour, A= Total Factor Productivity and $0 < \alpha < 1$)

$y = Y/L = AK^{\alpha} L^{1-\alpha}/L = AK^{\alpha}/L^{\alpha} = Ak^{\alpha}$

i. e $y = Ak^{\alpha}$ (GDP per worker is a function of Capital accumulation per worker)

A is the Total Factor Productivity function often interpreted as ' technology' or ' knowledge'.

The above production function is combined with a constant savings rate to predict that long term growth occurs through capital accumulation. Since there are diminishing returns to capital, then economies would hit a ' steady state' where the rate of depreciation of old capital is just equal to the rate of

replacement of capital stock. All economies tend to approach this steady state in the long run. (Solow 1956)

3. 0 Key predictions of the Solow-Swan model for empirical verification:

1. Is there a positive co-relation between the indicators of capital accumulation and economic growth as the model predicts?

2. If growth is indeed due to capital accumulation, then growth will be strongest when the countries have begun accumulation of capital and will slow down as capital accumulation progresses. Is this empirically observed?

3. The rate of interest i. e rate of return on capital should be highest in countries with lower labour productivity (seen from equation above) hence capital should flow from higher labour productive countries to lower. This would in turn cause faster development of the underdeveloped nations, and ultimately convergence. Has this been observed?

4. 0 Empirical test of the Solow-Swan Model

4. 1 Choice of Indicators:

The predictions of the model are tested by comparing Y/L with first, capital accumulation and then, human capital accumulation.

For Capital accumulation, the following indicators are chosen:

CO_2 emissions (kt) : As the level of industrial activity over the years has increased, the CO_2 emissions would have also increased proportionately. Therefore the level of CO_2 emissions each year can be a fair indicator of the amount of capital stock accumulated.

GDP per capita (constant LCU): The increase in capital stock accumulated will eventually translate into higher GDP, thereby increasing the per capita GDP. So GDP per capita can be a fair indicator of the capital stock accumulated.

Gross Fixed Capital Formation (constant LCU): this measure directly indicates the extent of capital stock accumulated. In the Solow-Swan model itself, investment is considered a direct determinant of growth.

For Human Capital accumulation, the following indicators are chosen:

Labor Participation rate, female (% of female population 15+) : an increased presence of women in the labor force indicates that the status of women has improved. Therefore a higher participation can be said to be a fair indicator that the human capital has grown.

Age dependency ratio (% of working-age population): a higher dependency ratio reflects lower human capital development and vice versa. This is because, a population with high dependency rates in working population indicates high unemployment as well as lower labor productivity.

Scientific and technical journal articles: the number of articles reflects the educational level and the skill levels of the general population. The higher the human capital, more will be the demand and supply of scientific articles.

4. 2 Results of Regression:

R2 Value/coefficient for Indicators and Y/L

Indicators

Australia

S Korea

Capital Accumulation (R2)

0. 866

0. 997

CO2 Emission

1. 750

1. 921

GDP per capita

-4. 273

6. 384

K*-K (point estimates)

0. 0091

+0. 0004

Gross Fixed Capital Formation

-2. 059

-2. 20

Indicators

Australia

S Korea

Human Capital Accumulation (R2)

0. 798

0. 997

Labor Participation rate

-0. 003

0. 147

Age Dependency Ratio

-4. 85

-0. 774

No. of Scientific Articles published

+3. 91

0. 00002

4. 3 Analysis of Results: (Refer enclosed excel sheet)

The graphs for K*-K for South Korea shows that initially there was little difference between the steady state and the current state of economic growth. Gradually this gap widened, and in the past decade this gap has reduced once again.

This shows that South Korea has attained its level of steady state through capital accumulation

The graph for K*-K for Australia does not show any regular pattern. Instead there is a zig-zag pattern along the horizontal axis, with the growth rate having surpassed the ideal state in some years and having fallen below in others.

This reflects that capital accumulation alone perhaps cannot explain the differences in K*-K. the shifts in steady state are perhaps caused by some other factor.

Overall, for South Korea there is a very strong correlation between Capital accumulation and productivity of labour. Australia also exhibits this relationship, albeit to a slightly lesser degree.

For Australia, it is seen that the regression coefficient for GDP per capita and Y/L is negative. One of the reasons for this could be that the capital per worker rate in the Australian economy has been considerably below the long run equilibrium steady state, therefore there would have been higher returns to capital and hence a lower Y/L value during these periods

Also, there is a very strong correlation between the indicators of Human Capital Accumulation and productivity of labour for both Australia and South Korea.

4. 4 Discrepancies of empirical findings with Solow Model :

1. For both countries, the GDP growth does not appear to be slowing down with increase in capital stock accumulation. The following two charts depict this fact :

GDP . v. Capital Stock (AUSTRALIA)

GDP . v. Capital Stock (SOUTH KOREA)

2. Also, regression results between Y/L and Population Growth rate and Gross savings rate of Australia and South Korea, are not consistent with the expected findings from Solow model.

SUMMARY OUTPUT of Regression of Y/L with Gross savings Rate and Population Growth for South Korea

Regression Statistics

Multiple R

0. 927465

R Square

0. 860192

Adjusted R Square

0. 840219

Standard Error

2. 026248

Observations

17

ANOVA

df

SS

MS

F

Significance F

Regression

2

353. 6524

176. 8262

43. 06869

1. 04E-06

Residual

14

57. 47951

4. 105679

Total

16

411. 1319

Coefficients

Standard Error

t Stat

P-value

Lower 95%

Upper 95%

Lower 95. 0%

Upper 95. 0%

Intercept

69. 17444

8. 986995

7. 697172

2. 14E-06

49. 89926

88. 44963

49. 89926

88. 44963

Gross Savings rate

-1. 01206

0. 29757

-3. 40108

0. 004304

-1. 65028

-0. 37384

-1. 65028

-0. 37384

Population Growth

-8. 23341

2. 262968

-3. 63832

0. 002686

-13. 087

-3. 37983

-13. 087

-3. 37983

SUMMARY OUTPUT of Regression of Y/L with Population growth and Savings Rate of Australia

Regression Statistics

Multiple R

0. 83054

R Square

0. 689797

Adjusted R Square

0. 645482

Standard Error

0. 003653

Observations

17

ANOVA

	df	SS	MS	F	Significance F
Regression	2	0. 000415	0. 000208	15. 56583	0. 000276
Residual	14	0. 000187	1. 33E-05		
Total					

16

0. 000602

Coefficients

Standard Error

t Stat

P-value

Lower 95%

Upper 95%

Lower 95. 0%

Upper 95. 0%

Intercept

-0. 00894

0. 018525

-0. 48261

0. 636832

-0. 04867

0. 030792

-0. 04867

0. 030792

Population Growth rate

0. 001384

0. 005547

0. 249464

0. 806625

-0. 01051

0. 01328

-0. 01051

0. 01328

Gross savings rate

0. 00467

0. 001148

4. 066277

0. 001156

0. 002207

0. 007133

0. 002207

0. 007133

(All Data from WDI, 2009)

From the Solow model, it would be expected that Y/L is positively correlated with savings rate and negatively correlated population growth rate. However, this is not entirely observed above.

5. 0 Theoretical explanation for empirical observations

Role of Technology So, there appears some other factors at work apart from capital accumulation that is increasing GDP growth in spite of increase in capital accumulation, and causing distortions in relation of Y/L with population growth rate and savings rate. Solow himself has offered an exogenous factor, i. e technology. As technological developments and innovations begin to appear in the economy, this moves the steady state up enabling the economy to keep experiencing economic growth without the effects of diminishing returns on capital setting in.

Role of Human Capital Mankiw, Romer and Weil (Mankiw 1992) offered another improvement over the Solow model. Through their study, they found that as Solow predicted Y/L was positively correlated with rate of savings and negatively correlated with population growth. However, they found that the share of physical capital in the total factor income was very high compared to what was empirically observed in the U. S economy. This led them to propose an ' augmented Solow model' wherein human capital accumulation

is also considered as a factor of production along with capital and labour. From our regression data above, it is already seen that indicators of human capital accumulation and Y/L show a very strong correlation.

Openness of Economy The Solow-Swan model assumes that it is a closed economy. However in reality, much of South Korea's growth was export driven. Sachs and Warner (Sachs 1997) have argued that countries with a liberal trade policy will experience higher growth. They have defined openness as the absence of non tariff barrier, more than 40% tariff rate, and a significant black exchange rate market, socialist economic system, and state monopoly of major export. (Sachs 1997)

Role of Institutions and Government policies J. Schumpeter has shown the importance of institutions in savings decisions and economic development. They have a direct bearing on the capital accumulation in a country. (Schumpeter 1912) Further the regulatory climate in the country and institutional norms also influence growth.

Data Deficiencies It is also possible that the above results are empirically incorrect due to the following errors:

Regression has been limited to only 16 years

Inaccuracy of historical data compared to current data

Incorrect choice of Indicators.