

## **How Effective Would the Solow Macroeconomic Growth Model be in Helping Developing Economies Like India to Achieve A Developed Status: An in-Depth Critical Analysis**

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DOI: 10.46609/IJSSER.2025.v10i01.010 URL: <https://doi.org/10.46609/IJSSER.2025.v10i01.010>

Received: 2 Jan. 2025 / Accepted: 14 Jan. 2025 / Published: 28 Jan. 2025

### **ABSTRACT**

*The Solow model adequately explained through empirical evidence, the industrialization of countries till the first half of the 20th century. The question is how to adapt this model to the current scenario of developing nations. There has been the Augmented Solow model which does to some extent, correct the basic assumptions and issues with respect to the 'Convergence Theory'. But there are still issues with respect to technology and Research and development transfers. These need to be addressed through various trade agreements , both bilateral and multilateral.*

**Keywords:** Solow Growth Model, Harrod-Domar Model, Free-Trade Agreements, electrification, Augmented Solow Model, East Asian Miracle, Steady State, Convergence theory, Capital coefficient.

**Research Question:** The relevance of the Solow macroeconomic growth model for developing economies in the current scenario. How does the external political and socio economic disturbances impact the working of this model? Do the external factors delay or enhance the adoption of this model? Are there any developing economies which have succeeded in moving from a developing status to a developed status according to this theory? These and many such questions would be attempted to be addressed in the course of this paper.

### **1. Introduction**

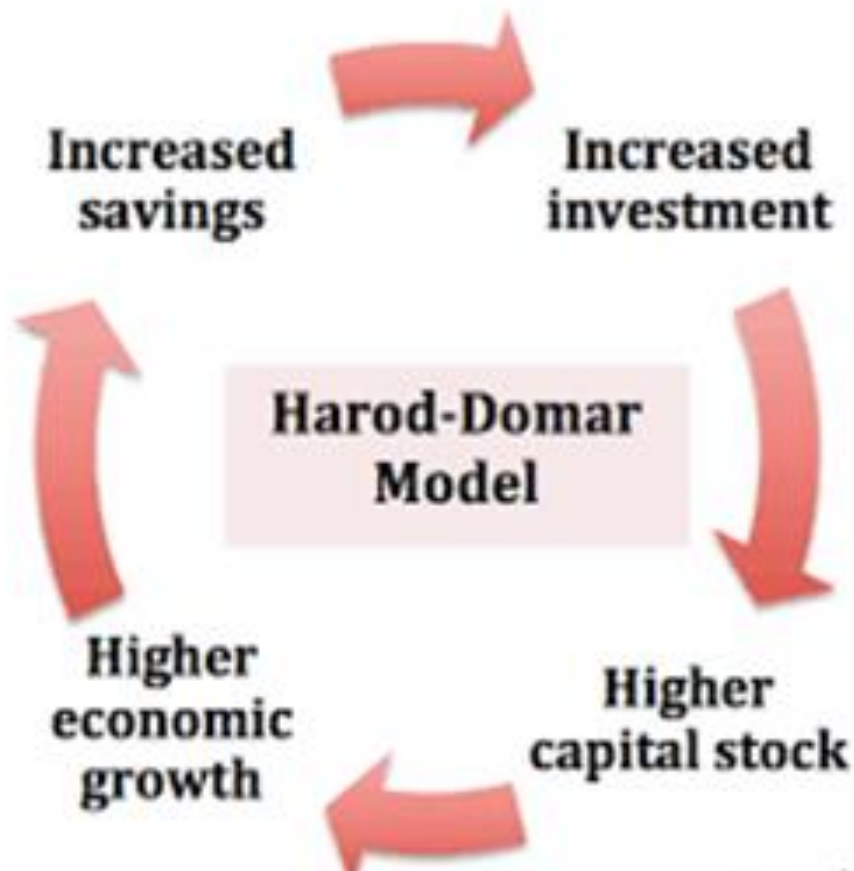
The Solow growth model is an exogenous model of economic growth that analyses changes in the level of output in an economy over time as the result of:

- Population growth rate

- Savings rate
- Rate of technological progress

This model was developed by Nobel prize winning economist Robert Solow. The important input in this model was the level of “technology”. It was the first neoclassical growth model and was based on the Harrod-Domar model. The Harrod-Domar model is depicted below

**Figure 1**



Source: <https://www.economicshelp.org/>

The basic idea of this model is that economic growth depends on the amount of capital that is available for investment, and that the rate of capital accumulation is proportional to the rate of savings.

The main assumptions of the model are as follows:

1. A full-employment level of income already exists.
2. There is no government interference.
3. The model is based on the assumption of a closed economy.
4. There are no lags in adjustment of variables.
5. The average propensity to save (APS) and marginal propensity to save (MPS) are equal to each other. Symbolically,  $S/Y = \Delta S/\Delta Y$
6. Both propensity to save and "capital coefficient" (i.e., capital-output ratio) are given constant.
7. Income, investment, savings are all defined in the net sense and hence they are considered over and above the depreciation.
8. Saving and investment are equal in ex-ante as well as in ex-post sense.

The Model's Key Points include:

**Investment:** Investment creates income and augments the productive capacity of the economy.

**Capital-output ratio:** A low capital-output ratio means an economy can produce a lot of output from a little capital. A high capital-output ratio means an economy needs a lot of capital for production.

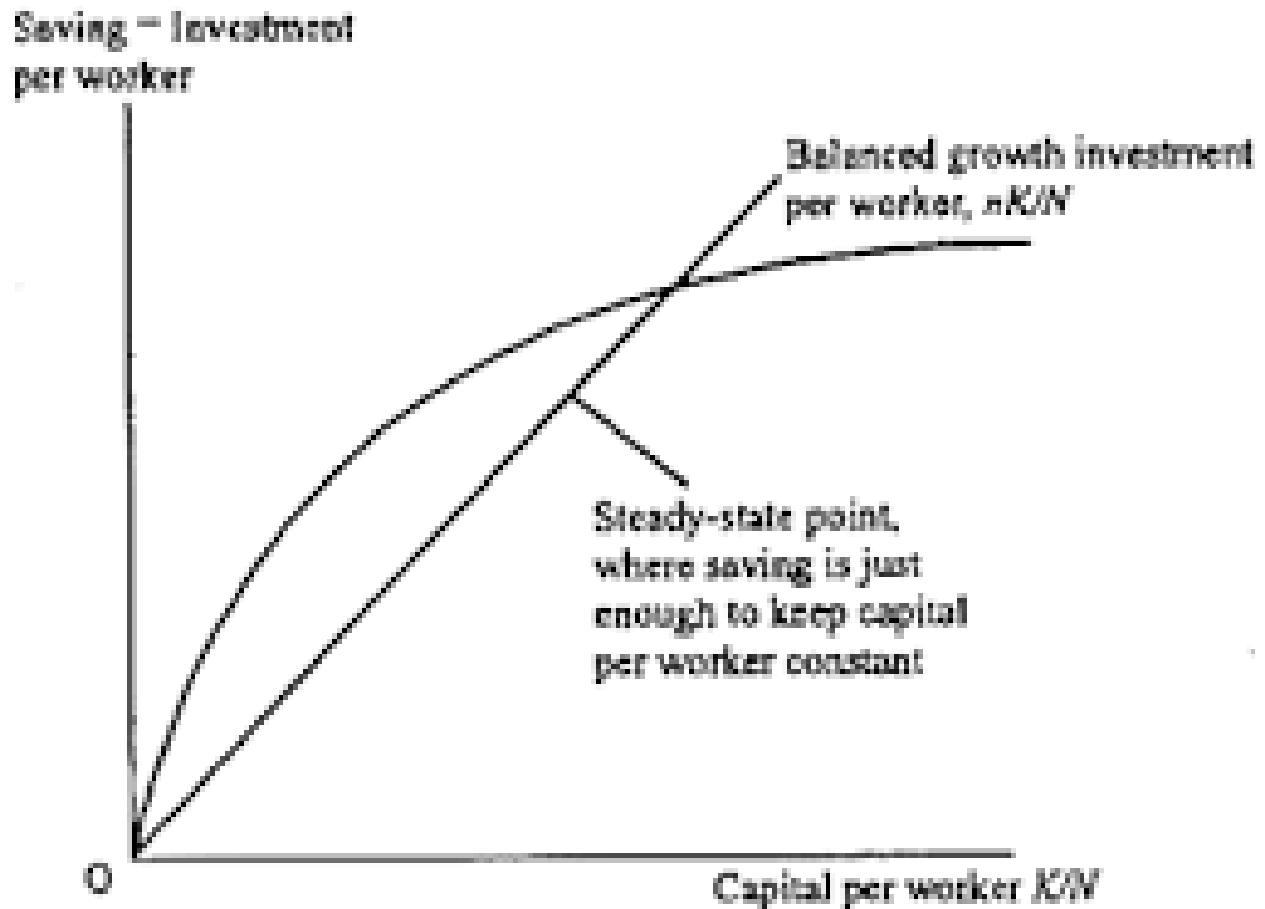
**Growth rate:** The model identifies three types of growth: warranted growth, actual growth, and natural rate of growth.

**Instability:** The model suggests that if investment deviates from a critical growth rate, full employment can degenerate into hyperinflation or depression.

Based on the Harrod-Domar model, Solow developed his growth model where "Knowledge" or level of technology are important inputs. Moreover, Labor(L) and effectiveness of labor(A) are assumed to grow. This would mean that there is a continuous increase in the productivity and importance of labor as a factor of production.

The Solow model clearly states that there is no growth in the long term because population is growing at the same rate as its depreciation and is equal to the savings in the economy, leading to a predicted convergence.

Figure 2



Source: <https://www.economicdiscussion.net/economic-growth/>

In the above diagram, Solow analyzes how higher saving and investment affects economic growth. Though there might be a slight discrepancy in the short run, where eventually higher savings and investment increase the rate of growth of both national income and output. According to this model, higher saving and investment would have no effect on the *rate of growth* in the long run where technology would have a greater impact.

His analysis was based on the fact that

- Output is always in balance with Work/productivity x Number of workers.
- To increase economic output, an increase in work/productivity or no. of workers is required.

Solow's growth model was discovered at a time when the world population rate was increasing. He first brought out the model in an article in 1956 but was conferred the nobel prize in 1987. During both the time periods, there was a continuous growth in world population. This is unlike the situation today, where the current rate of growth of world population is 0.87% , whereas it was 2.01% in 1956 and 1.8% in 1987. The relevance of this model would definitely be more applicable in the previous two time periods than maybe at the present status. As presently industrialized nations' populations are not growing anymore. Solow believed that the only way an economy can grow is through invention and innovation .

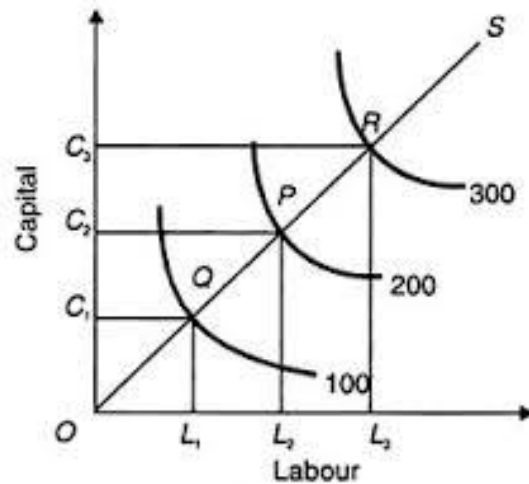
The standard Solow-model predicts that in the long run, economies tend to converge to the steady state equilibrium.

## **2. Solow Swan Growth Model**

The Solow Swan economic growth model focuses on long - run economic growth. It is significant for understanding the dynamics of economic growth.It provides a framework for understanding the impact of technological process and capital deepening in determining the growth rate of output per worker. The model is based on certain assumptions which are stated below

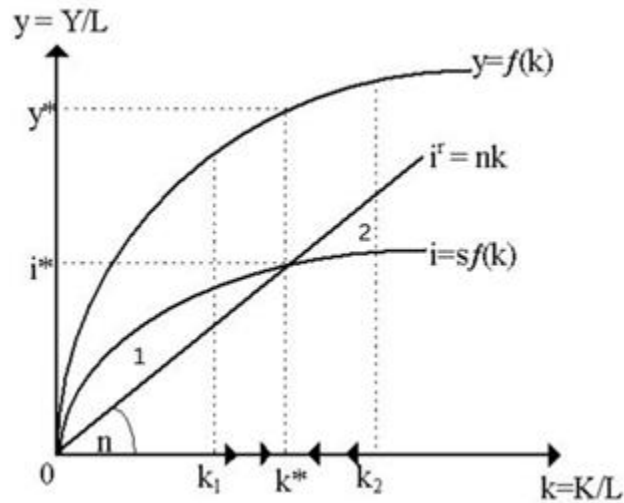
- Savings = investment
- Labour and capital are substitutable for each other
- Capital depreciates at a constant rate
- Population grows at a constant rate
- There are diminishing returns to an individual output.
- Full employment of labour
- Constant returns to scale
- (Based on the Cobb Douglas production function)
- Capital is both an input and an output in the model
- No technological progress

Fig. 3 : Visual representation of Cobb Douglas production function



Source: <https://www.economicdiscussion.net/production-function/the-cobb-douglas-production-function/18519>

Fig.4: Visual representation of the Solow Swan growth model



Source: <https://cruel.org/econthought/essays/growth/neoclass/solowgr.html>

The X axis in the graph represents **Capital per worker** and the Y axis in the graph represents **Output per worker**.

1. Depreciation curve( $i^r=nk$ ) - It is a straight line which shows that depreciation is proportional to the amount of capital . It means that with an increase in capital, depreciation also increases.
2. Production function( $Y=f(k)$ )- Output per worker is increasing at a diminishing rate as capital increases due to the law of diminishing returns.
3.  $i=sf(k)$  or investment curve - Whatever we have as saving, we invest.(S- Savings, i- Investment)
  - ❖ At point 1, the investment curve is higher than the depreciation curve, signifying that Investment > Depreciation. When investment is greater than depreciation, *capital grows*.
  - ❖ At point 2 the investment curve is lower than the depreciation curve, signifying that Investment < Depreciation. When investment is less than depreciation, *capital shrinks*.
  - ❖ The point where the investment curve and depreciation curve meet is known as the steady state or SS where investment = depreciation . *At this point, all the investment is used to maintain the depreciation.*

All this signifies that an economy will always end up at SS (where investment= depreciation).

### **3. Developed and developing economies**

In the initial state of development , the important ‘engine of growth’ of the first industrial revolution was coal and steam power. The growth impetus occurred due to fossil fuel discoveries and its application, primarily in the transportation sector with respect to the discovery of petroleum , internal combustion, engines and the most important is ‘electrification’. The discovery of cheap electricity in unlimited quantities led to the development of a new range of products and industries, example: electric light, radio and television, moving pictures, new material aluminum and super alloys which were used for the development of aircrafts and aerospace sectors. In this scenario, *energy consumption was as much a driver of economic growth as it was a consequence of growth*. Skills and knowledge embodied in the labour force are also a product of capital and labour . Solow indicated that developed economies that ‘ greed rationality and equilibrium was the basis for development as they depended on profit maximization for firms and utility maximization for individuals’. According to this, the theory is timeless as all people who function in the market work on the principles of rationality , which essentially means that producers want to maximize profits and consumers want to maximize utility.

Recent models after Solow have started incorporating new features where maximization involves differentiation with respect to independent variables; the number of variables is restricted under the input-output structure and growth in general equilibrium models implies growth in quantitative output( GDP) without structural change. The condition of fixed structural relationships can be modified by assuming smooth and gradual changes in some key sectors and allowing others to readjust.

#### **4. Solow model for developed economies**

Solow used the trajectory of developed economies to explain his growth model from real life data. His model was developed with the intention of explaining a few aspects of macroeconomics as it is not always feasible to explain all aspects of macroeconomics simultaneously. Solow developed his model where he deliberately ignored *short run fluctuations in employment and savings rate*. His main criteria was to develop a model that would describe the long run evolution of the economy. It has been universally accepted due to *useful insights into the dynamics of the growth process*. The Solow model in developed economies is based on the following equations which indicate the path of growth.

Capital accumulation takes place

$$K = sY - \delta K$$

The production function:

Constant returns to scale (a doubling of inputs leads to a doubling of outputs):  $A_t(\mu K_t)^\alpha (\mu L_t)^{1-\alpha}$

$$A_t(\mu K_t)^\alpha (\mu L_t)^{1-\alpha} = \mu^\alpha \mu^{1-\alpha} K_t^\alpha L_t^{1-\alpha} = \mu Y_t$$

$$Y = F(K, L)$$

- Decreasing marginal returns to factor accumulation (adding extra capital while holding labour input fixed yields ever-smaller increases in output)

$$\frac{\partial Y}{\partial K} = \alpha A_t K_t^{\alpha-1} L_t^{1-\alpha}$$

$$\left( \frac{\partial^2 Y}{\partial K^2} \right) = \alpha(\alpha - 1) A_t K_t^{\alpha-2} L_t^{1-\alpha} < 0$$

Steady state growth:

$$sf(k^*) = \delta k^*$$



For reference:

Y: output Stock or GDP

K: Capital Stock

L:Labor

y:Output Per worker

k:capital per worker

s:savings rate

$\delta$ : Depreciation rate of capital

Mankiw et al (1992) stated that the Solow model has impressive empirical explanatory powers in two ways:

1. The empirical version produces parameter estimates whose signs and statistical significance are predicted by the theory.
2. The 'conventional goodness of fit' explains over 40% of the cross-country variation in growth rates.

The above are reasons why the Solow growth model has become the baseline for other growth models. The disadvantages of the model are stated below:

1. This model was based on the experiences of developed economies. In spite of it being a model for long run growth, there have been instances where it has not adequately explained the lack of long run growth as the per capita income does not necessarily grow in the long run.
2. Aggregate income grows exogenously at a given rate  $n$ , which the model is unable to explain.
3. In current literature different countries have different production functions and to assume an identical Cobb Douglas would not adequately describe the growth theories of the economies.
4. Growth model should take into account parameter heterogeneity of various countries.

## **5. Relevance of the Solow model for developing economies today**

The application of the Solow growth model to developing economies necessitates a nuanced interpretation, acknowledging both its foundational insights and its limitations in capturing the complexities of economic development.

Developing economies in the 21st century are different from those that developed in the earlier one. The world dynamics have significantly changed since the earlier developed economies like Britain, other parts of Europe, America, and Japan and even since the East-Asian miracles. The issues that they face today are with respect to structural and institutional challenges which would lead to different growth trajectories than those stated or anticipated in the Solow model. The most important amongst them are:

- Lower levels of capital accumulation
- Constraints in human capital development
- Infrastructural deficiencies
- Efficient institutional

The global scenario with respect to transference of technology, inadequate investment in research and development, and the absence of a supportive policy environment are deterring factors that allow these economies to follow the development trajectory suggested by the Solow model.

The existing world politics with respect to trade and technology relations are extremely dynamic and at times, a deterrent to the development of emerging market economies . This type of situation did not exist in the case of East-Asian miracle Countries when they were charting their course to development.

The research and development in developing economies is inhibited due to lack of capital expenditure. These economies have a limited extent of domestic capital expenditure and would rather invest them in basic infrastructure and various such areas that ensure maximum linkage with respect to removal of poverty and increasing job opportunities. This technical input is an integral part of the Solow framework. For developing economies like India, the dependence on this is exogenous from developed economies .

Within the ambit of developing economies, their heterogeneity with respect to their ability to absorb, adapt , and innovate are majorly influenced by:

- Government Policy
- Educational system
- Regulatory environment of the developing economy

### **5.1 Attempt to reconcile the original Solow model to the current environment.**

Accumulation of human capital should also be taken into account as it is correlated with savings and population growth. It has been evidenced in recent years that countries have failed to converge in per capita incomes. In fact, if this model is applied to various countries, then it could predict that *each country finds its own different steady-state of growth*. If human capital is taken into consideration then poorer countries would tend to have higher rates of return to physical and human capital. The newer growth models tend to look at the determinants of saving, population growth and worldwide technological change as endogenous rather than being treated as exogenous.

To adopt the Solow model for developing economies it was necessary to plug the disadvantages in the original model. By doing that, a new version of the model is now being adopted which is known as the '*Augmented Solow Model*'. The difference between the models is that the latter one takes into account human capital which could consist of education ,health, or both as an additional input in production.

This model was then adopted for the Chinese economy by Sai Ding and John Knight in their article in ScienceDirect (Journal of Comparative Economics, Volume 37, September 2009) and it was found to be a fairly good fit when both human capital and structural changes were taken into consideration, as China's relative success in economic growth has been due to high physical capital investment, conditional convergence gain, dramatic changes in the structural employment and output and low population growth. There were 4 main determinants of China's extraordinary growth . Capital formation is an important factor which leads to the view of *investment driven growth* that is in line with explanations given for the '**East Asian Miracle**' as has been indicated by Krugman (1994), and Young (1995). China achieved this growth through productivity enhancing structural change with low population growth due to the restrictive population policy that the country followed.

As far as india is concerned, the adoption of growth models needs to incorporate optimising behaviour of households and firms in the economy .The factors that need to be considered are:

- Rates of time preference

- Degree of openness to trade
- The level of services provided by the government
- Degree of protection of property rights

The rate of an economy's growth is affected by the present distance from the steady-state (the more distant the steady-state, the faster the growth) as well as whether there are shifts in the steady state itself. A large number of economists have indicated that the important part of growth is *not the convergence* to a steady state, but the factors *which affect the steady-state itself*.

Due to India being a vast country with a high population, there are regional disparities amongst various states. These disparities are enormous and persistent.

- They are a form of dispersion of per capita income.
- Literacy rates
- Rates of urbanization
- Social and demographic indicators.

Due to these factors, the growth level of various states has progressed at various levels.

For example: In 1996, Punjab had more than 3 times the income level than Bihar. Maharashtra for the same period, grew annually at 3.4% while Bihar income levels remained almost stagnant. As far as population is concerned, for 1996, Tamil Nadu and Kerala grew at 1.4% and 1.5% percent respectively, whereas it 2.5% in Rajasthan and 2.4% in Manipur. In 1971, Kerala had a literacy rate of 60% while other states had a rate of 40%. In 1991, Kerala was on the top of the list while literacy was concerned, whereas Bihar and Rajasthan have remained the most illiterate states.

## **6. Impact of globalization and liberalization on the adoption of the Solow model in developing economies.(FPI, FDI,Technology transfer,Aid)**

The existing circumstances with respect to political equations in the world have led to governments of developing economies working towards enhancing trade and policy measures, both amongst their neighbouring countries as well as with the developed economies of the world, such that the issue of transference of technology is overcome. In the case of India, this can be envisaged in both bilateral and multilateral trade agreements which have been signed by the government to:

- Strip away trade barriers
- Reduce or eliminate tariffs

- Promote investment
- Economic growth
- Transference of technology

India currently has preferential access, economic cooperation, and free trade agreements with 54 individual countries . India has signed in recent years 13 free trade agreements and six limited coverage preferential trade agreements with various countries. These trade agreements are treaties in which a country promises to lower trade barriers.

This underscores the need for a more dynamic interpretation of the Solow model, one that recognizes the potential for policy and institutional reforms to mediate the relationship between technological progress and economic development.

First and foremost, it is fair to say that economic growth cannot be completely explained as dictated by endowments and advances in technology. According to the Solow model, there is an extensive approximation between capital per worker and output per worker. Even so, while the Solow model can further be used to study the key determinants of economic growth, there is a need to scrutinize its assumptions and inherent limitations for its applicability to developing economies. These economies already face challenges as they start to catch up with larger economies, and there are hidden opportunities within those challenges, therefore the economies cannot overlook creativity and the innovation solutions. They must also enhance their institutional frameworks and encourage technological progress. By adopting more comprehensive methods to economic progress and development, particularly those combining the prescriptions and critique of the Solow model with the elements of the endogenous growth theories, most developing economies tend to make sense of a more complicated modern global economy and therefore find the right strategies for growth and economic development.

The global system of WTO has lowered trade barriers through negotiations and operates under the principle of nondiscrimination This results in reduced costs of production ( because the imports which are used in production are usually cheaper). Prices of finished goods and services are also reduced, which leads to more choice and ultimately a lower cost of living. It also shows that the improving state of facilitation performance can be linked to the improved health-related products such as vaccines which, in turn, would boost usage. Another example is the price of insulin . The price of Insulin has various determinants, open trade being one of them:The higher the level of competition between manufacturers, the lower the price of insulin. In summary, lowering trade barriers on health products can make a substantive contribution to building up health systems and lowering out-of-pocket payments of patients.

The problems that countries like India face in accepting WTO agreements are with respect to :

- Trade protocols - developing economies' products may be rejected if they don't meet trade protocols and customs.
- Subsidies- developed economies may pressurise developing countries to lower their tariff and government subsidies.
- Legal and administrative reforms- Emerging market economies might need legal and administrative reforms to fulfill WTO agreement commitments.
- Capacity building- Developing economies might need to build capacity so that they are in a stronger bargaining position during negotiations .
- Adaptation and mitigation policies- Developing countries might need to develop policies such that they can fight the adverse impact of globalization .
- Shrinking policy space- developing economies may face shrinking policy space due to global commitments.
- Agriculture sector- India has always been protective of its agricultural sectors and when it enters into FTAs(Free-Trade Agreements). This sector is more often than not left out .
- Intellectual property rights - WTO agreements have led to India being forced to accept more international patents.
- Democratic freedom and human rights - These rights can impact negotiation.

Some other criticisms of WTO is that it is undemocratic and unaccountable and has increased global inequality and insecurities , promoting unsustainable production and consumption patterns and eroding diversity.

## **7. Conclusion and the way ahead**

The Solow model was based on empirical data in the early 20th century and predicted correctly the variables, constraints , assumptions , and treatment of capital to describe the convergence theory. Subsequently, the Augmented Solow model was developed which took into account aspects of assumptions especially for developing economies and the availability of capital.

Countries today, with increased liberalization and globalization, are favoured to allow technology transfer. But in recent times, there have been various barriers amongst the countries of the world who have set up various laws e.g. Intellectual property rights etc. which prevent the easy transference of technology. The only option out in such cases is that individual developing

nations set up their own trade agreements -bilateral and multilateral- to encourage development of their economy. Forums like the WTO have their own disadvantages , especially for developing economies like India . The only way that one can achieve the success that the Augmented Solow model indicates is through easy access to advanced technology and research and development.

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