AN OVERVIEW OF ENDOGENEOUS GROWTH MODELS: THEORY AND CRITIQUE

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Abstract

The inability of neoclassical growth model in explaining long run economic growth is due to the existence of diminishing returns in capital. Thereforeendogenous growth theory that models long run economic growth through technological transfers is necessitated. By reason of the obvious complex nature of modeling, the paper focuses on the intuition that the Endogenous Growth Model endeavors to capture. Thus, the paper provides to the reader, a non- technical overview and critique of the endogenous growth model, key literature in the study of the mechanism of the model as well as providing important references. The intended audiences are policy makers and analysts, students and optimistically anyone without a great deal of economic training.

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1. INRODUCTION

By definition and convention, an economy can be said to be experiencing economic growth when there is a sustained annual increase in the real national income over a period of time (Ahuja, 2012). That is, economic growth means a rising trend of net national product. This definition has been critiqued by economist as unsatisfactory and inadequate in the sense that it does not take into consideration rising populations within economies as well as macroeconomic variability (example: inflation). They argued that the possibility exist where incomes may be increasing but the standard of people may be falling. Therefore, a more common alternative tothe definition of economic growth (by how it is measured), involves the use of rates of growth in income per capita – taking into consideration the ability of an economy to expand its output faster than its growing population – and the levels and growth rates of real per capita Gross National Income (GNI) – taking into consideration how much of goods and services are available for consumption and investment to the average citizen – to measure overall economic well-being of citizens.

In making a case for the necessity of understanding economic growth for any economy, the most compelling reason is that economic growth determines the material well being of the people. It dictates to a large extent the availability of resources within a society and invariably the choice patterns of individuals in trying to satisfying their utility preferences. Accelerating economic growth within an economy has been argued to be the solution of absolute poverty as well as converging economies (Dreze and Sen, 2002). The relationship between economic growth and inequality presents another essential reason for understanding growth. Economists have postulated that growth reduces inequality (Sala – I – Martain, 2006); others have shown that the relationship changes over time (Kuznets, 1955).

To fully grasp the concept of economic growth, there is a need for a formal theory; for organizing the facts, clarifying causal interdependencies and relationships, as well as espousing possible relationships that may exist. In understanding economic growth, as in the general study of economics, an argument not founded on a clear theoretical framework is seldom informative. The starting point for conceptualizing economic growththeory and Endogenous Growth Models (EGM) in particular, is the Neoclassical Growth model (NGM). While the focus of NGM was primarily on the growth of productive inputs; savings, capital accumulation (associated with depreciation) in determining economic growth, the EGM builds upon postulates of NGM and focuses on how innovations and technology can lead to economic growth in the long run.

Given the unavoidable complex nature of modeling, the paper will focus on intuition that the EGM endeavors to capture. Thus, the paper provides to the reader, a non- technical overview and critique of the popular endogenous growth model, key literature in the study of the workings of the model as well as providing important references. The intended audiences are policy makers and analysts, students and optimistically anyone without a great deal of economic training. The rest of the paper is organized as follows: in section 2 a brief precursor (neoclassical growth model) to endogenous growth model is overviewed. In section 3, the paper reviews three endogenous growth models and in section 4 provides the critique to the model. The paper concludes in section 5.

2. The Neoclassical Growth Theory (NGM)

The start point for any study on economic growth is the neoclassical growth model (NGM)(Solow, 1956 and Swan, 1956). The basics of the model are that capital accumulation

drives economic growth in the short run. This can be achieved through economic policy that encourages people to save more. However,in the long run, the NGM concludes that growth rates will revert to the rate of technological progress, which NGM takes to be exogenously determined – being independent of economic forces. Thus, the NGM is pessimistic about long run economic growth. It explains this pessimism using the principle of diminishing marginal productivity, which places a boundary to how much output a person can produce simply by working with more and more capital.

In less technical terms, consider an economy with a given level of supply of labor and technology which is assumed to be constant over time. Suppose this labor works with an aggregate capital stock[1] *K*. the maximum amount that can be produced depends on *K* according to an aggregate production function. For simplicity, a Cobb Douglas production function is assumed[2]. Constant returns to scale – doubling all units will lead to doubling output – are commonly assumed in this production function. However, due to the assumption of constant labor supply, decreasing returns will occur when one input increase (in this case capital) and the other remains constant (Labor). This implies that as more capital is employed, given fixed labor, its contribution to output declines.

Based on the Cobb Douglas production, the NGM relates the changes in output as input factor increases. Key to this is capital accumulation[3]. In this model, capital is accumulated by saving a proportion of output in each period and investing it in new capital and a fraction of the capital stock disappears each year due to depreciation.

Savings,
Depreciation,
Output

[1] K here is an aggregate index and it include both human and physical capital.
[2] The production function will be of the form: $Y = F(K, \bar{L})$ with $F'(K) > 0$ and $F''(K) < 0$
[3] Capital is accumulated through net investment, *I*: where $I = sY - \delta K$. Where s is the fraction of output saved and δ is the fraction of output that depreciates.

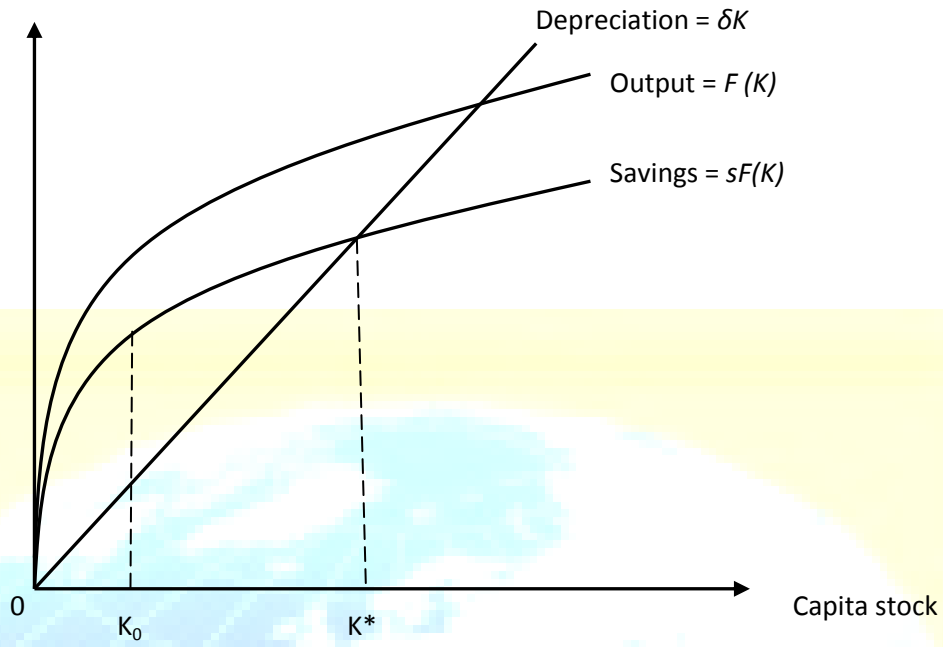

Figure 2.1
Short run growth as determined in neoclassical growth model

In this model it is capital accumulation through saving a fraction of total output in each period that brings about increases in output and ultimately economic growth. From figure 2.1, the shape of the output curve depicts diminishing returns – output increases at an increasing rate, gets to a maximum and reduces – while the savings curve is a fraction of output. The straight line captures the amount of savings that will be just enough to keep up with capital depreciation. Given the production function$Y = F(K)$, where Y is output and depends on the level of capital, K, increases in K will lead to increases in Y but not by as much as the increase in K. Assume initial capital is K_0, at this point, savings exceeds depreciation and there is enough savings to buy new capital, induce investment and increase output. This process continues until savings can no longer match depreciation and capital remains at K^* in the long run thereby halting any further increase in output and economic growth.

The implication of the NGM is that savings (capital accumulation) can account for growths in output in the short run. However, long run growth rates cannot be explained by the model. Further increases in the savings rate will only increase the steady state level of capital stock and not change output levels. To stimulate increases in output, the output curve will expand outwards over time; signifying that capital becomes more productive at each time period thereby countering the growth – destroying tendency of diminishing returns. For capital to become more productive in each time period, there has to be some form of technological progress that is capital leaning. Thus, theinevitability of the NGM to predict long run growth rates heralded the endogenous growth models that emphasized technological progress in predicting long run growth rates.

2.1. Relevant Literature on Neoclassical Growth Models (NGM)

The pioneering articles on neoclassical growth models were by Solow(1956) and Swan(1956) where exogenous saving rates where the main focus. Endogenous saving rates where later developed by Cass (1965) and Koopmans (1965). Based on the neoclassical framework, other studies were later on developed: Sidrauski (1967) included money and inflation in the neoclassical framework; Brock and Mirman (1972) analyses the neoclassical model with uncertainty; Barro (1990) studied the implication of government spending in the model; Mankiw, Romer and Weil (1992) used human capital to illustrate convergence in the neoclassical theory; Caselli and Ventura (2000) allow for household heterogeneity; Jones and Manuelli (2005) provide a very simplistic version of the neoclassical model.

3. Overview of Endogenous Growth Model (EGM)

Endogenous growth models describe a collection of theories that model economic growth through the medium of technological discoveries and progress. As seen in the neoclassical growth model, economic growth is determined by the rates of savings and capital accumulation. Technological discoveries have no part to play in this growth process and thus taken as exogenous – determined outside the model- and given. However, according to Aghion and Howitt (1998) there are ample reasons to believe that technological progress can depend on economic decisions of economic agents. In the EGM, technology progress is seen as the core determinant of long run economic growths which the NGM could not account for. Hence, technological progress becomes endogenous in endogenous growth models.

Recall, that it is the effect of diminishing returns in the neoclassical growth model that limits the expansion of output and economic growth. To overcome this restriction to economic growth, EGM inculcates increasing returns to scale. The classical Cobb Douglas production function exhibits constant returns to scale to the factor inputs. This leaves no reward or incentive for economic agents to engage in activities that encourage technological progress. Thus any theory that endogenizes technological progress cannot be based on competitive equilibrium where factors are rewarded according to their marginal products.

For simplicity and better understanding, this paper will elaborate on 3 (three) of the most common endogenous growth models:

a) The *AK* model

b) Product Variety Model

c) The Schumpeterian Growth Model

3.1 The *AK* Model

The models of endogenous growth are primarily concerned with establishing how technological progress can bring about increasing returns to scale. The *AK* model by Arrow (1962) emphasizes the possibility of productivity depending on output per worker. This implies that technological progress can occur, though unintended, by "learning by doing". As workers continue to specialize in the production process, the productivity of their input will become higher through this specialization. Technological progress in the *AK* model is modeled as the difference in the initial productivity of the factor before learning by doing and the productivity of the factor after learning by doing – which will be higher.

The *AK* model is very similar in its postulates of what drives economic growth with the neoclassical growth model. In the *AK* neoclassical growth model, economic growth is induced by savings and capital accumulation, whereas in the *AK* model, economic growth is induced by savings, capital accumulation, and efficiency. Efficiency is defined as the increase in the productivity of factor inputs by "learning by doing".

3.2 PRODUCT VARIETY MODEL

The inability of the *AK* model to prescribe an adequate description of long run economic growth motivated other endogenous growth models that emphasized innovation- horizontal innovations. These innovation based endogenous growth models consist of two parallel branches of which the product variety is one, and the other, the Schumpeterian growth model. The product variety model postulates that economic growth is a consequence of the expansion of specialized intermediate variety of products. As already noted, modeling increasing returns to scale, in a clear and concise manner, explains long run economic growth. The product variety model does

this by insisting that growth is driven b innovations that lead to the introduction of new varieties. As summarized:

> "Productivity growth is driven both by increased specialization of labor that works with an increasing number of intermediate inputs and by the research spillovers, whereby each new innovator benefits from the whole existing stock of innovations. Ideas are non – trivial, which means they can be freely used by new innovators in their own research activities. And they are excludable in the sense that each new innovation is rewarded by monopoly rents. It is the prospects of these rents that motivate research activities aimed at discovering new varieties".
>
> Aghion and Howitt (1992)

The basic product variety model can be characterized into the interactions of 3 (three) sectors – the research sector – produces research outputs, intermediate goods sector – buys research output from research sector and produces intermediate goods (inputs for final sector) and the final goods sector – combines labor and intermediate goods to produce the final good (Mare, 2004). It is the interaction of the roles of these three sectors that mitigate the problem of diminishing reruns in modeling long run economic growth.

In the research sector, spillovers are intuitively assumed. These spillovers occur because innovations in the research sector are non – rival and partially excludable. What this means is that, once innovations (blueprints, product designs, etc) come out, other researchers can see it and can develop additional innovations. Also, the researchers have the opportunity of getting some rewards from these innovations through patents and property rights which they can sell off

to the intermediate sector. This creates an imperfect market for these innovations and the opportunity of rewards for innovation.

When intermediate sector buys these patents and property rights, they create a form of monopoly power in that they hold the exclusive right to the use of the innovation. Increasing returns to scale occurs in the intermediate sector if there is an increase in patents (intermediate goods) and more intermediate firms (varieties of intermediate goods) enter the sector with the same marginal productivity (Mare, 2004). Hence more patents leads to more intermediate products and because of the non – rival nature of innovations and spillovers, will lead to an increase in the variety of intermediate goods. This limits the effects of diminishing returns in explaining economic growth. In the final good sector, the intermediate goods and labor are combined to produce the final good for consumption.

The implications of the product variety model depend on the assumptions that are inherent. These assumptions are; Spillovers in research and innovation powerful enough to limit diminishing returns and monopoly power in the intermediate sector with respect to the use of innovations in the research sector. The model as a whole postulates that economic growth increases with the productivity of research, as well as with labor supply[4].

3.2.1 Relevant Literature on Product Variety Model

Romer (1987) provided a growth model with expanding product varieties with lon run growth being stable by using expanding sets of input to mitigate diminishing returns. Romer (1990) modeled the product variety, including a R&D sector that generates designs for new inputs through horizontal innovations. Grossmanand Helpman (1991a) present the product variety

[4] The idea that economic growth increase with labor supply implies that larger countries should grow faster. This however is disputed by Jones (1999) who concluded that growth rate have remained relatively stable despite a substantial increase in the number of researchers in the United States.

framework with an expansion of consumer products that enter the utility function. Grossman and Helpman (1991b) have used the product variety model to analyze the effect of market integration on economic growth. Acemoglu and Zilibotti (2001) integrated directed technological change into the frame work of expanding varieties to explain productivity differences across countries.

3.3 The Schumpeterian Growth Model

This model of economic growth emphasizes that growth is generated by a sequence of quality improving or vertical innovations. It is called Schumpeterian because it embodies the forces that Schumpeter (1942) describes as "creative destruction" – innovation that drive growth creates new technology and at the same time destroys older technology by making them redundant. This model is similar to the product variety model in emphasizing innovations and research spillovers as drivers of economic growth. However, while the product variety concludes that it is the sum total of expanding varieties of intermediate goods that induces economic growth in the long run, the Schumpeterian growth model insists that it is the possible improvements (creating better intermediate goods) in the intermediate sector that explains long run economic growth.

The mechanism of the Schumpeterian growth model is similar to that of the product variety. However, in the Schumpeterian model, growth results from the rise in the productivity of the intermediate input by increasing the quality of the intermediate good. The researcher can successfully innovate – creating a new version of the intermediate goods which is more productive – or can be unsuccessful, making innovation uncertain and probabilistic. This uncertainty increases as technology advances because it becomes harder to improve upon technologically advanced intermediate products. Given the uncertainty and difficulty in

innovating, the researcher is rewarded a monopoly profit which is compared to the cost of embarking on the research in order to maximize research profits. Thus, uncertainty and maximizing monopoly research profits determine the frequency of innovations – how long it takes for innovation to occur – as well as the size of innovations – the productivity effects of innovations ; two concepts that are paramount in explaining long run economic growth in a Schumpeterian frame work.

In the Schumpeterian Growth model, diminishing returns is mitigated by creative destruction. Better intermediate goods are provided for the final sector for the production of consumer goods. This form of innovation through creative destruction has the following implication on the model:

1) Economic growth increases with the productivity of innovations. This gives importance to health and education as growth enhancing variables.
2) Economic growth increases with the size of innovations. This emphasizes the need for countries lagging behind the world technological frontier, to successfully create policy that helps implement this technology and get rewarded with larger productivity enhancements.
3) Stronger property rights induce economic growth. This limits the imitation of innovation in the intermediate sector, thereby encouraging more research as it protects profits accruing to successful researchers.
4) Scale effects exist. Increased population will induce economic growth. The intuition is that, there will be an increase in the market size for successful entrepreneurs and an increase in the pool of researchers.

3.3.1 Relevant Literature on Schumpeterian Growth Models

Segerstrom et al (1990) provided the seminal approach to modeling vertical innovation. They modeled growth with product improvements in a fixed number of sectors without uncertainty in innovation. Aghion and Howitt (1988) and Reinganum (1989) modeled vertical innovation using techniques from industrial organization theory. Kortum (1997) and Segerstrom (1998) developed semi – endogenous models to determine the scale effect on economic growth.Dinopoulos and Syropoulos (2006) also about the efforts to build barriers to entry are what remove scale effects in a Schumpeterian framework. Laincz and Peretto (2004), Ha and Howitt (2006) and Ulku (2005) concluded that a Schumpeterian model without scale effects are more consistent with long run trends in R&D and TFP (total factor productivity) than semi – endogenous growth models.

4. Critique of Endogenous Growth Models

In the paper, three endogenous growth models – AK model, Product Variety Model and the Schumpeterian Growth Model – were overviewed in a very simplistic manner for even the layman. However, this overview will not be complete without highlighting the drawbacks of these models, according to the literature. In a general sense, Endogenous growth models as a whole depend to a large extent on assumptions of the neoclassical theory which has proven inadequate for developing economies. The endogenous growth models abstract from reality wrongly by assuming the symmetry of sectors in the economy or that there is a single product market. Inefficiencies arising from poor infrastructure, institutional inadequacies and perfect markets, institution and transaction costs are some common variables that impede economic

growth in developing economies. It also neglects the political nature of innovation – where countries create a strong barrier to innovations.

In specific terms, starting with the *AK* model, the model did not explicitly differentiate between capital accumulation and technological progress. It lumps up all the characteristics of capital together with all the characteristics of technological progress. Also, the neoclassical proponents have argued that the *AK* model cannot explain cross country convergence – when a country grows faster if it is farther below its steady state.

For the product variety model, it fails to capture the role of exit and turnover (creative destruction) in the growth process. Even though there is strong evidence of exit and turnover of firms in inducing productivity growth (Comin and Mulani, 2007). The Schumpeterian model on the other hand is plagued with the problems of scale effects – concluding that larger economies can induce economic growth – and the absence of capital's role in the growth process. The model also neglects the problem of financial constraints by assuming perfect financial markets: in reality some financial markets work better than others.

5. Conclusions

The impact of endogenous growth models can be deduced from its conclusions on the roles and dynamics of innovations and discovery, introduction of new approaches to modeling economic growth, and a different perspective from the neoclassical growth theory.Endogenous growth models are an important theoretical framework for understanding the growth process. They highlight inter – relationships within the society that helps policy makers. These theories are important because they emphasize that capital accumulation and innovations can induce economic growth, while diminishing returns can reduce it. These models show how long run

economic growth can be achieved through spillovers and scale effects of ideas and research within the economy.

References

Acemoglu,D., and F. Zilibotti. (2001). "Productivity Difference." Quarterly Journal of Economics, 119, 565 – 611.

Aghion, P. and P. Howitt (1988). "Growth and Cycles Through Creative Destruction." Mimeo, MIT.

Aghion, P. and P. Howitt. (1992). "A model of growth through creative destruction," *Econometrica*,60, pp. 323–51.

Aghion, P. and P. Howitt. (1998). *Endogenous growth theory*, Cambridge, MA: MIT Press.

Ahuja, H.L. (2012) *Modern Economics (17th Edition)*. New Delhi: S. Chand & Company.

Arrow, K. J. (1962). "The economic implications of learning by doing," *Review of EconomicStudies, 29:1, pp. 155–73.*

Barro, R.J. (1990). "Government Spending in a Simple Endogenous Growth." *Journal of Political Economy, 98,103 – 125.*

Brock, W. and L. Mirman. (1972). "Optimal Economic Growth Under Uncertainty: The Discounted Case." *Journal of Economic Theory, 4,497 – 513.*

Caselli, F., and J. Ventura. (2000). "A Representative Consumer Theory of Distribution." *American Economic Review, 90, 909 – 926.*

Cass, D. (1965). "Optimum Growth in an Aggregative model of Capital Accumulation." *Review of Economics Study, 32, 233 – 240.*

Comin, D., and S. Mulani. (2007). "A Theory of Growth and Volatilityat The Aggregate and Firm Level." *Proceedings, Federal Reserve Bank of Francisco.*

Dinopolos, E., and C. Syropoulos. (2006). "Rent Protection as a Barrier to Innovation and Growth." *Economic Theory, 32, 309 – 332.*

Dreze, J. and A. Sen (2002). "*India: Development and Participation*." Oxford University Press.

Grossman, G.M., and E. Helpman. (1991a). "*Innovation and Growth in the World Economy*." Cambridge, MA: MIT Press.

Grossman, G.M., and E. Helpman. (1991b). "Quality Ladders in the Theory of Growth." *Review of Economic Studies, 58, 43 – 61.*

Ha, J., and P. Howitt. (2006). "Accounting for Trends in Productivity and R&D: A Schumpeterian Critique of Semi – Endogenous Growth Theory." *Journal of Money, Credit, and Banking, 39, 733 – 774.*

Jones, C.I. (1999). "Growth: With or Without Scale Effects." *American Economic Review, 89, 139 – 144.*

Jones, L.E., and R.E. Manuelli. (2005). " Neoclassical Models of Economic Growth: The Effects of Fiscal Policy, Innovations and Fluctuations." In Aghion,P. and S.N. Durlauf (Eds). *Handbook of Economic Growth*. Amsterdam: Elsevier North – Holland.

Koopmans, T. C. (1965). "On the Concept of Optimal Economic Growth*." In The Econometric Approach to Development Planning*. Amsterdam: North – Holland.

Kortum, S. (1997). "Research Patenting and Technological Change." *Econometrica,65, 1389 – 1419.*

Kuznets, S. (1955). "Economic Growth and Income Inequality." *American Economic Review, 45, 1 – 28.*

Laincz, C.A., and P.F. Peretto. (2004). "Scale Effects in Endogenous Growth Theory: An Error of Aggregation, Not Specification." Mimeo.

Mankiw, N.G., Romer,P., and D.N. Weil. (1992). "A Contribution to the Emperics of Economic Growth." *Quarterly Journal of Economics, 107, 407 – 437.*

Mare, D.C. (2004). "What do Endogenous Growth Models Contribute?" Motu working Paper, 04 – 04.

Reinganum, J.F. (1989). "The Timing of Innovations: Research, Development and Diffusion." In Schmalensee,R., and R.D. Willig (Eds.). *Handbook of Industrial Organisation*, Vol.1. New York: North – Holland.

Romer, P. (1987). " Growth Based on Increasing Returns Due to Specialization." *American Economic Review, 77, 56 – 62.*

Romer, P. (1990). " Endogenous Technological Change." *Journal of Political Economy, 98, 71 – 102.*

Sala – I – Martain, X (2006). "The World Distribution of Income: Falling Poverty and Convergence Period*." Quarterly Journal of Economics, 121, 351 – 397*

Schumpeter, J.A. (1942). "*The Theory of Economic Development*." Cambride, MA: Havard University Press.

Sergerstrom, P.S., Anant, T., and E. Dinopoulos. (1990). "A Schumpeterian Model of the Product Life Cycle." *American Economic Review, 80, 1077 – 1092.*

Sidrauski, M. (1967). "Rational Choice of Patterns of Economic Growth in a Monetary Economy." *American Economic Review, 57, 534 – 544.*

Solow, R. M. (1956). "A Contribution to the Theory of Economic Growth." *Quarterly Journal of Economics, 70, 65 – 94*

Swan, T.W. (1956). "Economic Growth and Capital Accumulation*." Economic Record, 22, 334 -361*

Segerstrom, P.S. (1998). "Endogenous Growth without Scale Effects." *American Economic Review, 88, 1290 – 1310.*

Uklu,H. (2005). "*An Empirical Analysis of R&D – Based Growth Models*." Mimeo, Manchester University.