New Formulation of Classical Growth models with Technology as a Factor of Production

Dr Mahuamita Deb
Assistant Professor
Department of Economics
Gobardanga Hindu College
West Bengal

Abstract: *Technology is a dynamic concept. It undergoes continuous changes brought about by the improvement in the existing level of knowledge. It is manifested in the production process and changes that are taking places. The indispensability of technology for economic growth is an established fact. However, the classical economists paid little or no attention to this essential factor of production. The emphasis was on labour power and capital formation. The Classicists did recognise the significant role of technology but lacked the proper understanding to explain the simultaneous expansion of output and increase in population growth rate and the rise in world per capita output during the 19th Century. Schumpeter recognised the power of technology and its change but the rigorous effort took off in the post Keynesian-era after the emergence of growth literature by Harrod and Domar. Indeed Keynesian analysis paved the way for growth theory with Harrod and Domar introducing the much needed dynamism in economic analysis. However, the entire responsibility of generating growth is restricted to capital accumulation and investment in Harrod-Domar analysis; the model ignores innovation as source of growth. The paper argues that per capita output growth can be generated in the classical growth models of Malthus, Ricardo and Marx by considering technical progress as a factor of production.*

Key words: Technology, Labour, Classical and Keynesian Analysis

Introduction: Neoclassical economist Paul Romer used the term ideas rather than the more traditional terminology technology. Ideas come from knowledge. Thus technical progress is advancement of knowledge. It is the outcome of translation of scientific discovery, invention or in other words creation of knowledge to ease out the difficulty, of performing work. It increases an economy's ability to produce goods and services. Technology, the centrifugal element in economic growth is treated in a dormant way by the classical economists. The growth model developed by Harrod and Domar in the post Keynesian era explained the static situation devoid of dynamism because their model was simple extension of Keynes's macroeconomic model which dominated economic thinking in the 1940s.Technology as a matter of fact, did not receive serious attention in classical understanding. The stress was on labour power and capital accumulation. Contribution of technology could not be properly surfaced.

Rudimentary ideas of technological change and its power were not completely unknown to Classical economists like Marx. Schumpeter made a discrete change in the direction by introducing the concept of technology as creative destruction to enhance productivity.

The paper is an attempt to trace the historical path in an analytical way. The likelihood of output growth surpassing the rate at which population grows indicating the role of technology behind the spectacular 19th century per capita income growth in the western economy is somewhat explored by reconsidering the classical growth models. The work is organised into three sections: Section I reformulates the classical growth models of Malthus and David Ricardo with technology as a factor input. That the introduction of technical progress as a factor of production can alter the conclusion of the Marxian growth model is dealt with in Section II. Section III concludes the paper.

SECTION-I

Economic growth is a phenomenon which raises human welfare or causes an increase in welfare-enhancing output. Adam Smith in his '*Wealth of Nations*" clearly indicated that economic growth could continue indefinitely if there were no obstacles to the division of labour and specialisation. His optimism may have been based on his view of specialisation not so much as a provider of onetime gains in efficiency but as an incentive to further technological progress.[1] "*The invention of all those machines by which labour is so much facilitated and abridged, seems to have been originally owing to the division of labour. Men are much likely to discover easier and readier methods of attaining any object, when the whole attention of their minds is directed towards the single object, than when it is dissipated among a great variety of things*".[2]Thus it can be said that sustained growth can occur if division of labour and specialisation go on unhindered. They prepare the ground for innovation.

We can get a glimpse of Smith's view regarding how technical progress influence labour from the already mentioned lines "The invention of all those machines by which labour is so much facilitated and abridged…." indicates that labour hours are cut-short and their task made easier by new machines as some of their skills get embodied in new machines. The impact on capital can be read from the lines "Men are much likely to discover easier and readier methods of attaining of any objects……."..In other words, installations of new and better capital goods increase productive capacity of capital. Investment (improving the quality of capital) is inversely related to labour requirement. A greater investment in new capital goods is consistent with the labour- saving technical progress- increase in capital-output ratio (following Harrod's classification of technical progress).

The prevailing Classical view after Smith was very pessimistic about the process of economic development. It was focussing on the problems of rapid population growth in the face of fixed supply of land and the combined effect exerted on the rate of profit in industry by rising food prices due to diminishing returns to capital. One of the foremost misanthropists was Malthus (1766-1934). Malthus the early 19[th]century British Economist developed the first rigorous model of economic growth. His model was a "classical" one inspired by the thinking of John Stuart Mill and David Ricardo. His logical reasoning led him to conclude that the world economy was doomed to stagnation and most likely to eternal poverty. Fortunately for humanity, Malthus's conclusions proved to be erroneous.[3]

Malthus presented his thoughts on economic growth entirely on verbal terms, but his reasoning can easily be converted into modern style of modelling of growth theory[4]. He considered the economy as one big farm where the output is a function of labour and land and the amount of land is fixed in quantity though labour can grow or contract. Since production without capital is unthinkable, we can write the production function of such an economy as

---

[1]Economic Growth and Development : Hendrik Ven Den Berg
[2] Wealth of Nations-Adam Smith : 1776, Book-2, P-364.
[3]Economic Growth and development, Hendrik Van Den Berg
[4]Thomas Malthus-An Essay on the Principle of Population, London: Pickering

$$Y = f(L, K, N)$$

Where Y is real output

L denotes the labours employed

N the fixed supply of land and

K is the amount of physical capital.

The production function is subject to diminishing returns to capital and labour. Diminishing returns is caused by a disproportionate use of one or more factors relative to others. In Malthusian style of model diminishing returns could arise when increasing quantities of capital and labour were combined with a fixed amount of land.

The total amount of land being fixed, real output can change according to the following equation,

$$dY = MP_L \partial L + MP_K \partial K,$$

The RHS denotes the change in real output caused by the combined effect of the changes in labour force and capital stock; MPs being the marginal productivities of the respective factors. Marginal productivity theory dictates that a firm's profit maximisation motive drives it to pay a factor according to its marginal product. Substituting w & r for marginal products of labour and capital respectively,

$$dY = w\partial L + r\partial K$$

The basic relationship can be expressed as

$$\frac{1}{Y}\frac{dY}{dt} = \frac{wL}{Y}\frac{\partial L}{\partial tL} + \frac{rK}{Y}\frac{\partial K}{\partial tK} \dots\dots\dots\dots\dots\dots \text{ (i)}$$

Where $\frac{1}{L}\frac{\partial L}{\partial t}$ = rate of growth of labour force

$\frac{1}{K}\frac{\partial K}{\partial t}$ = rate of growth of capital stock.

Here $\frac{wL}{Y}$ is the labours share in total output and $\frac{wL}{Y} = \frac{\partial Y}{\partial L}\frac{L}{Y}$ is the elasticity of output w.r.t labour. Similarly, $\frac{rK}{Y}$ is the output elasticity w.r.t capital. Denoting the growth rates of total output, labour and capital by y, l & k respectively and $\frac{wL}{Y}$ by α and $\frac{rK}{Y}$ by β, equation II(i) can be written as

$$y = \alpha l + \beta k \dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\text{(ii)}$$

Where α+β<1

Again, α=w/Y/L=Marginal product of labour/Average product of labour and β=Marginal product of capital/Average product of capital.

This shows that the rate of growth of output (y) is the weighted sum of the growth rates of capital (k) and labour (l) respectively, the weights being the ratios of the marginal and average products of the two factors of production. Subtracting (the rate of growth of labour force) from both sides of equation (ii), we get the growth rate of per capita output as follows:

$$Y - l = \alpha l - l + \beta k$$

$$= \beta k - l(1-\alpha) \dots\dots\dots\dots\dots\dots\dots\dots \text{ (iii)}$$

Hence rate of growth of per capita output is raised by the growth rate of real capital weighted by its share in the total product (determined by its marginal product) and depressed by the growth rate of labour force weighted by (1-α). Malthus hypothesised that as labour is combined with a fixed supply of land, production is subject to <u>diminishing returns.</u> That is, as additional workers are employed, output increases by smaller amounts because each additional worker has less and less land to work with. Though capital accumulation in the economy was not inconceivable, but it played no role in influencing the productivity of any of the factors of production including capital itself. Following Malthus's reasoning, as the number of workers increases, output rises, but due to diminishing returns output rises by smaller and smaller amounts, causing per capita output to fall.

Malthus's second hypothesis that population growth is a function of real per capita output will now cause population growth to slow down, preventing further fall in per capita output. So from equation (iii), the increase in L and the consequent fall in α more than offsets the rise in k (α falls at a rate greater than the rate at which l increases) justifying the fall in per capita output in Malthus's model.

Hence the assumption of diminishing returns to labour together with population growth as a function of real per capita output causes the economy always reverting to the subsistence level of per capita output.

Malthusian model failed to accommodate the reason behind the 19th century economic growth. Malthus could not predict that output growth rate would be higher than the rate of growth of population. His conclusion that the world would be poured into eternal poverty was due to his failure in recognising the technical progress as the force that can cause output to grow more rapidly than the rate of growth of population. If technical progress were accounted for, capital accumulation and growth of labour force would have been accompanied by the increase in their respective productivities and our eqn.(iii) transforms into the following form

$$Y-l = \beta k - l\,(1-\alpha) + t \ldots\ldots(iv)$$

Where t represents growth rate of technical progress

Eqn. (iv) shows that the rate of growth of per capita output is increased by the rate of growth of capital weighted by β and depressed by rate of growth of labour weighted by $(1-\alpha)$ and raised by the technical progress. New capital stock bringing about technical progress raises both α and β. α, β are the ratios of marginal to average productivities of labour and capital respectively and the marginal product exceeds the average product when both are rising. Further technical advancement opens up the possibility of substitutability between land and other factors of production (considered later) overcoming the problem of fixed supply of land.

According to Malthus effective demand must grow in line with productive potential if profitability as a stimulus to investment is to be maintained, but his theory could not guarantee this. Malthus emphasised that savings of the landlords were falling short of the planned investment of capitalists and the possible imbalance between the supply and demand for capital were impeding growth. Savings fell short of investment in Malthus's model because the falling marginal productivities of both labour and capital raised the cost of production of the landlords squeezing profits. Malthus undermined any productivity improvements of the factors of production due to undervalued role of technical progress. He typically belonged to a period which witnessed minimal or negligible advances in the production process (Industrial Revolution started in Great Britain almost two decades after Malthus's death). Indeed, no path breaking innovation revolutionised the entire production system during his time. This would have created ignorance regarding the role of technical progress on economic growth in Malthus's mind.

David Ricardo was another classical economist who also underestimated the role of technical progress in influencing the sources of growth. Like Malthus, he predicted that the capitalist economies would end up in a stationary state, with no growth owing to diminishing returns. He constructed a model which demonstrated that sooner or later growth would not be possible because of scarcity of natural resources.

According to Ricardo, growth is a function of capital accumulation and capital accumulation depends on reinvested profits. Profit is the residual output after making contractual payments to labour, capital and land. If the producer himself is a landlord then profit includes both the remuneration of landlord and land. If production is demand driven then a rise in demand for food (corn) due to population pressure, will raise the price of corn raising profits. Ricardo demonstrated that producers would move on to a lesser and lesser fertile land when the supply of fertile land is exhausted and population pressure causes corn prices to shot up. Consequently, more labour and capital are employed to produce more output. Initially output increases as more labour and capital are being employed. Gradually, diminishing returns sets in due to disproportionate use of labour and capital relative to land. Hence Ricardo observed "There is no limit to demand-no limit to the employment of capital while it yields profit, and that however abundant capital may become there is no other adequate reason for a fall in profit but a rise in wages"[5]. As profits fall to zero, capital accumulation ceases, heralding the stationery

---

[5]The Principles of Political Economy and Taxation, 1817

state. Further Ricardo said "A real rise of wages is necessarily followed by a real fall in profits and therefore when the land of a country is brought to the highest state of cultivation, when more labour is employed, it will not yield in return more food than what is necessary to support the labour so employed, that country has come to the limit of its increase both of capital and population"[6].

Unlike Malthus, Ricardo considered capital accumulation as a factor affecting growth of output but he did not recognise the role that capital accumulation plays in enhancing the productivity of land, labour and capital in generating growth. The negative impact of diminishing returns to labour and capital (in the face of scarcity of fertile land) on output growth could be overcome by technical progress in agriculture. Technical progress inducing capital intensive method of production saves land also. For example, in modern-day agriculture, fertilisers enable more productions per acre of land and the quicker maturing High Yielding Variety of seeds makes it possible to use each acre more than once during a year. Both act as land saving innovations. The quicker maturing characteristics of High Yielding Variety of seeds give rise to a shorter harvesting period, making it possible for farmers to practice multiple cropping in the same land. Thus, new technology in agriculture requires a more intensive use of the fixed factor, land. Fertilisers, High Yielding Variety of seeds, pesticides, pumps, tractors etc., are the fruits of technical progress that saves land and increases the productivity of labour. Few labours are required to plough large acres of land by tractors, threshers or combine harvesters. All these explain the increase in α and β caused by an increase in t in eqn. (iv) and the consequent rise in per capita output. Considering technical progress overcoming the fixity of land eqn.(iv) can be rewritten as

$$Y-l=\beta k-l(1-\alpha) +g\mu+t' \text{…...... (v)}$$

Where g is the proportional growth rate of fertility of land

μ is the output elasticity w.r.t land

And $\alpha+\beta+\mu>1$

t' is the new level of technology.

Here per capita income will grow at a higher rate than that considered in eqn.(iv) totally offsetting the depressing effect of rising population growth rate and diminishing returns to labour and capital.

SECTION-II

Karl Marx formulated a theory of capitalist economic development. Marx predicted in his theory, laid out in Das Capital (1867) the collapse of capitalism. Like Ricardo, Marx also assumed that the supply of labour to the modern industrial sector is infinitely elastic at an institutionally determined subsistence wage rate, which works as a basic support for rapid capital accumulation. He based his explanation on the existence of the surplus labour force beyond productively employed workers in the industrial sector, called the "industrial reserve army". Such labours are readily available to accept employment at the subsistence wage rate and hence as long as this reserve army exists, the industrial wage rate is prevented from rising above the subsistence level. Starting off with the labour theory of value Marx argued that workers are paid their labour values, that is the amount needed to buy the subsistence goods to keep the population constant, but they are made to work more hours. Marx assumes that while it is possible to exploit labour by not paying them according to their productivity, it is unlikely to exploit machinery and plant which Marx called constant capital. As accumulation proceeds, he argues that constant capital will rise in relation to labour. Marx introduced the term variable capital representing the proportion of capital invested in wages to purchase labour power. It is this capital according to Marx which generates surplus value over and above the minimum subsistence wage. The surplus values accrue to the capitalists.

---

[6]The Principles of Political Economy and Taxation, 1817

According to Marx the economy does not grow forever, but the end comes not from a stationary state but from "crises" associated with overproduction and social upheaval.[7] Typical to the other classical economists, capitalist's surplus was considered as the sources of capital accumulation and growth by Marx. To have an understanding about "Marxian Crises", we consider his analysis in brief.

The Marxian model assumed that the gross output consisted of three elements- a) the wage bill (w) (b) constant capital (k) i.e., plant and machinery and the raw materials used in production and (c) surplus value or profit (s). The wages of labour are determined by the minimum subsistence level. Surplus value is the difference between output per worker and minimum wage per worker.

If Y represents the total output of the capitalist (or industrial) sector, L the labour force, w the minimum subsistence wage rate, the surplus value s is given by

$$S = \frac{Y}{L} - \frac{W}{L} \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \text{(vi)}$$

The rate of surplus value or what Marx called the "*degree of exploitation*" is given by s/v where v is the sum of variable capital and constant capital (or total capital). The ratio of surplus value to total capital gives the rate of profit, which can be written as

$$\pi = \frac{s}{W+k} = \frac{\frac{s}{W}}{1+\frac{K}{W}}$$

Marx envisaged as capital accumulation proceeds constant capital will rise in relation to variable capital. The rate of surplus value or the rate of profit will fall because the exploitable component of total capital declines as a proportion of the whole. He predicted that as capital accumulation occurs "the reserve army of labour" would disappear driving wages up. The capitalists then either attempt to keep wages down or substitute capital for labour raising $\frac{k}{W}$. Marx believed that the desire to invest is inherent characteristic of the capitalists. Substitution of capital for labour not only raises the $\frac{k}{W}$ ratio but also causes consumption demand to fall as labours are rendered unemployed leading to a "realisation crisis" created by the fall in effective demand. Lack of effective demand results in the fall of y and hence s and these together with the rise in $\frac{k}{W}$ causes the erosion of capitalist profits. Capitalism eventually collapses through its "inner contradictions" and power passes to the working classes.

Marx's analysis contains valuable insights into the functioning of capitalism, but his prediction, like the prediction of his predecessors have not materialised. Just as the other classical economists underestimated the role of technical progress in agriculture as an offset to diminishing returns, Marx also did not recognise that technological innovation and capital investment in industry could affect the productivity of labour. Ricardo had developed his theory in the late18th century during the Industrial Revolution when automation (based on new power sources like steam engine) had not yet been highly developed. He viewed capital invested in the development of a factory production system was a factor contributing to the wage fund.[8] In contrast, by the mid-19th century when Marx developed his theory there was full-fledged utilisation of steam-powered machines, and the share of constant capital in total capital increased. As a result, relative to rapid capital accumulation and output growth, employment increased slowly. Perhaps this propelled Marx to envision machinery & equipment as instruments embodying human skills and new industrial technology that can only replace labour for capital. That an efficient army of labour emerges after the introduction of new machines and equipment were not considered by Marx. As the available technology improves, the efficiency of labours also rises. For instance, the efficiency of labour rose when assembly-line production

---

[7] A. P. Thirlwall, *Growth and Development*, Palgrave McMillan, 8th edition
[8] Wage fund is defined as the sum of payments to labour and payments to purchase of tools & structures complementary to the use of labour

transformed manufacturing in the early 20th century, and it rose again when computerisation was introduced in the late 20th century. If technical progress was accounted for, the productivity of labour would have risen at a greater rate than the wage rate causing s to rise in eqn.(vi).Thus, as capital is substituted for labour, so that $\frac{k}{w}$ rises, s would also rise consequent upon the rise in average productivity of labour $\frac{y}{L}$; eventually profit rises instead of eroding away. Technical progress ensures there is no necessary clash between real wages and the rate of profit.

Marx's death in 1883 put a pause on the further advancement of growth and development theory and it lay effectively dormant for nearly the next sixty years. Economists during the period excepting a few ceased to concern themselves with explaining the unprecedented rates of growth experienced by many countries during the decades before the first world war. The spectacular growth of the world economy in the late 1800s and the concomitant improvement in the way of living of the World population in clear defiance of **Malthus** caused economists like Alfred Marshall to treat growth and development as a "natural" phenomenon. According to them growth is like an evolutionary process akin to biological developments in the natural world.

SECTION-III

Conclusion

The above analysis on classical growth theories reflects the basic classical ethos that the diminishing returns to capital, drives down the rate of profits frustrating capital accumulation and growth of per capita output in the long run. Diminishing returns due to the fixity of land in the presence of increasing population growth rate is overwhelmingly responsible for the classical illusion regarding the falling rate of growth of per capita output. The classicists however, emphasised on the capital accumulation and increased participation of labours as the sources of output expansion despite diminishing returns overlooking the role of technical progress in the production process. Addition to labour force apart from other changes in the production process induces mutation- more heads in the labour force means more minds, more thoughts and more minds germinate more ideas. More ideas translate into new ways of using labour and capital to produce more output.

Capital accumulation is also associated with some transformations. Qualitative changes in production techniques take place due to the addition of new capital to the existing capital stock. In other words, new capital is endowed with the new way of mixing the factor inputs hence changes in the production process are experienced. Changes in productivity particularly, labour productivity and qualitatively improved output became familiar through the later growth models (neo-classical growth models) but the associated changes in the composition of labour requirement have been ignored. Adequate attention has not been paid to induced heterogeneity in labour utilisation and obsolescence of some type of labour requirement. Indeed, technical progress induces reduction in the use of some kind of labour and start demanding for some other type.

REFERENCES

Paul Romer; "Ideas Gaps and Object Gaps in Economic Development" Jr. of Monetary Economics, Vol.32,1993.

Amartya Sen; Growth Economics, Penguin modern economics Readings,1970.

Robert J. Barro and Xavier Sala-i-Martin; Economic Growth (Second Edition), MIT Press 2004.

Hendrik Van Den Berg; Economic Growth and Development (Second Edition), World Scientific Publishing Company Ltd., Singapore.

Thomas Malthus; An Essay on the Principle of population, London, 1798.

Adam Smith; An Inquiry into the Nature and Causes of the wealth of Nations, Book-2, University of Chicago Press, Chicago,1776.

A.P. Thirlwall; Growth and Development (Eighth Edition), Palgrave McMillan.

R.F. Harrod; "An Essay in Dynamic Theory" Economic Journal, Vol.49, 1939.

G.M. Grossman and E. Helpman; Innovation and Growth in the Global Economy, MIT Press, Cambridge, 1991.

P. Howitt and P. Aghion; "Capital Accumulation and Innovation in Long run Growth", Jr. of Economic Growth, Vol.2, No.2,1998.