Economic Growth and Information Technology: A Note

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November 2005

ECONOMIC GROWTH AND INFORMATION TECHNOLOGY: A NOTE

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Abstract

The usage of information technology (IT) towards sustainable economic growth is found to yield three main effects: (1) an efficiency effect , (2) a scale effect, and (3) a capital utilization effect. The first two effects are multiplicative whereas the third effect is additive on aggregate output productivity. In essence, this paper suggests that IT is more productive only if the economy is capable of replacing its sustainable capital resources at a rate exceeding that of consumption sacrifice.

I. INTRODUCTION

The impact of information technology on globalization of the world market holds multiple effects from an economic point of view. Those effects, whether direct or indirect, concern themselves with a new business model of a more flexible organizational structure, shrinkage of the production supply-chain, a drastic shortening of distribution lead-times, and a dramatic decline in consumer search costs. They also hold, however, larger financial risks and a more vulnerable and volatile business environment, which may not necessarily transfer its technological efficiency into short-run profits. In addition, customization of goods and services, based on the efficient specialization of resources and on product differentiation, may fuel consumer demand to a point where aggregate business supply may not meet demand equilibrium at reasonable prices. Those market-based effects, when aggregated across different sectors of an economy, will ultimately lead to macroeconomic effects which may alter the growth path of aggregate output, and hence alter the development process of an economy.

The decomposition of aggregate economic effects towards macroeconomic growth through the use of information technology - as an *indirect* factor input in an economy's aggregate productive resources - is the main concern of the current article. A simple inquiry of the impact of information technology (IT) onto the sustainable growth path of a typical Neoclassical (Solow-type) growth economy is the main approach undertaken here. The analysis is very simple indeed and such is the approach found most comfortable by the author. The methodology of analysis is based on a Neoclassical growth model for a competitive economy with augmented labor and physical capital as primary productive factors and with information technology as an indirect factor of production on aggregate output.

II. THE MODEL FRAMEWORK

Neoclassical economic growth models assume three direct factors of production: physical capital accumulation (*K*), labor (*L*), and aggregate productivity of knowledge (*A*); for an economy-wide aggregate production function of the form (Stokey 1991, Lucas 1988, and Solow 1956 & 1957)[2]:

(1) $$Y = F(AL, K)$$

(2) $$y = f\left[\frac{K}{AL}\right] = f(k)$$

where *Y* is aggregate output, *y* is output per effective labor ($y \equiv \frac{Y}{AL}$), and *k* is capital per effective labor ($k \equiv \frac{K}{AL}$). Capital (*K*) is assumed to be the depreciated cumulative amount of investments in a national economy, whereas aggregate production is assumed to be under full employment, and output (*Y*) is assumed to be constant-returns-to-scale. The following *Inada* conditions due to scarcity of capital resources are assumed to hold for a converging solution:

[3] $$\lim_{k \to 0} f'(k) = \infty \quad and \quad \lim_{k \to \infty} f'(k) = 0$$

When capital is scarce, its marginal productivity is large; and when capital is fully exhausted, its marginal productivity approaches zero. The solution for a sustainable balanced-growth-path (BGP) for $\dot{k} = 0$ without the inclusion of information technology can be easily verified to be:

(4) $$sf(k) = (\delta + n + g)k$$

where δ denotes capital depreciation, *n* the rate of labor population growth, *s* the aggregate savings rate, and *g* the rate of effective technological progress (rate of local innovation).

III. ASSUMPTIONS ON THE USE OF INFORMATION TECHNOLOGY

Denoting the continuous and differentiable variable "*i*" to be the effective use of information technology in a given capital stock of an economy, we assume the following conditions to hold:

$$k(i) > 0, \quad \delta'(i) < 0, \quad \delta''(i) > 0, \quad n'(i) = 0, \quad g'(i) > 0, \quad and \quad g''(i) < 0 .$$

These conditional assumptions imply that more use of information technology increases the rate of local innovation ($g'(i) > 0$) and has no effect on labor population growth ($n'(i) = 0$). Further, it is assumed that capital depreciation (δ) can be written as an additive function of idea depreciation (*d*) and physical capital depreciation (ρ), as follows:

(5) $$\delta(i) = d(i) + \rho$$

In essence, (5) implies that the use of IT has no direct effect on the rate of physical capital depreciation (ρ), yet it also implies that more use of IT *decreases* the rate of idea depreciation through spill over outcomes (hence the previous condition of $\delta'(i) < 0$, since $d'(i) < 0$ with $\rho'(i) = 0$). Further, such a rate of decrease is diminishing (i.e. convex) in absolute value hence suggesting $\delta''(i) > 0$. Also, the use of IT positively affects the rate of local innovation but at a diminishing rate ($g''(i) < 0$). Such a diminishing property stems from the diminishing marginal product assumption of factor resources.

IV. GROWTH EFFECTS

Re-solving balanced growth equation (4) to include information technology as an indirect factor of production in the growth path of an economy, and utilizing the assumptions above, we get:

(6) $$f'(i) = [d'(i) + g'(i)]\frac{k(i)}{s} \quad .$$

Equation (6) states that the effective *exogenous* utilization of information technology $[f'(i)]$ is a *multiplicative* function of two major effects: (a) *an efficiency effect*: $[d'(i)+g'(i)]$, and (b) *a scale effect*: $\frac{k(i)}{s}$.

A typical developing economy is capable of utilizing information technology along two major lines of progress. The first (the efficiency effect) is due to idea creation and effective local technological innovation. The second (the scale effect) is due to monotonic scale transformations of the productive base of an economy, from one level of technology to the next. The efficiency effect could be thought of as a *flow* process of technological innovation through the use of information technology, while the scale effect could be thought of as a *stock* process whereby the productive base of an economy scales itself up the technological ladder via the use of information technology.

Expanding on our simple Neoclassical model and *endogenizing* the choice of information technology - whereby the economy's capital is set free to choose its own level of information technology and degree of utilization - we get the following result (by totally differentiating Equation (4) with respect to "*i*", and utilizing our main assumptions in (2), (3) and (5)):

(7) $$s\left[f'(k)\frac{\partial k(i)}{\partial i} + f'(i) \right] = [d'(i) + g'(i)]k(i) + \frac{\partial k(i)}{\partial i}[d(i) + \rho + n + g(i)]$$

which means:

(8) $$f'(i) = [d'(i) + g'(i)]\frac{k(i)}{s} + \left\{ \frac{\partial k(i)}{\partial i}\left(\frac{\delta(i) + n + g(i)}{s} - f'(k) \right) \right\}.$$

When the capital resources of an economy are left free to choose their level of utilization of "*i*", the growth effect of information technology on sustainability contains a new *additive capital utilization effect*, in addition to the multiplicative effects of Equation (6). This additive effect depends upon the rate of *replacement capital* in the economy ($\delta(i) + n + g(i)$) in relation to the aggregate savings rate (*s*). In particular, the new effect is stronger as:

(9) $$\delta(i) + n + g(i) > sf'(k)$$

This suggests that productivity gains from information technology require the following to hold: the rate of replacement capital when IT is utilized should exceed the marginal productivity of capital due to savings. Hence, IT is more productive only if the economy is capable of replacing its sustainable capital resources at a rate exceeding that of consumption sacrifice.

V. LIMITATIONS AND A FINAL REMARK

This proves, from a theoretical standpoint, the positive effect information technology can have on the developmental process of an economy through its efficiency, scale, and capital utilization effects. However, since research space is relatively limited, so is our theoretical standpoint. A cross-country empirical study of the theoretical model is needed to better assess the extent of the proposed model (on the likes of Mankiw, Romer and Weil, 1992). Human capital and education are also influential variables on the quality of an economy's output, yet are essentially omitted in our simplistic model. The role of telecommunications infrastructure on the efficient use of information technology should also be empirically tested within the economic growth model developed above. Also, since any model's conclusions is always limited by its core assumptions, then it should be noted that the conclusions of "growth effects of information technology" set forth above are limited by the assumptions of its previous section.

A final thought cannot be left unwritten. Although the use of IT has been proven to promote economic openness, the advent of cheap information access may yet to carry unlimited capabilities in terms of *social openness*. Cultural and religious influences on the use of IT have to be taken into account, and respected, when promoting information technology and Internet use within developing countries. Beyond economics: attribution, cultural perception, and social ethics cannot be ignored. The use of the Internet and IT should be utilized to open up the horizons of different cultures and traditions, to help in the removal of media stereotyping, and to provide for effective and inexpensive means for cultural exchange – an exchange characterized by understanding and mutual respect. This may prove even more helpful to future world generations than the mere business consequence of economic exchange[3].

REFERENCES

LUCAS, R., "On the Mechanics of Economic Development," *Journal of Monetary Economics* 22 (1988), 3-42.

MANKIW, N., D. ROMER, and D. WEIL, "A Contribution to the Empirics of Economic Growth," *Quarterly Journal of Economics* 107 (1992), 407-437.

SOLOW, R., "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics*, 70 (1956).

SOLOW, R., "Technical Change and the Aggregate Production Function," *Review of Economics and Statistics*, 39 (1957).

STOKEY, N., "Human Capital, Product Quality, and Growth," *Quarterly Journal of Economics*, 106 (1991).

ENDNOTES

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[2] National output is assumed to obey a "Harrod-neutral" labor-augmenting aggregate production function.

[3] I have initially written this comment before the tragic events of September 11, 2001. Let us then hope and pray that the advent of cultural exchange – through the uses of information technology – can prove more helpful to younger generations of the world than the mere business consequence of economic exchange, and that social openness can someday encircle our religious and political differences towards the benefit of a yet unborn generation.