Technology and Economic Growth

Technology has a general and a specific meaning. Solow (1957) used the specific concept of technology as a shift of the production frontier or the production possibility frontier. It tends to reduce costs and improve the long-run productivity of firms and industries. In its general and broader meaning, technology characterizes the organizational structure of an industry that includes all its managerial skills and investments in R&D. Schumpeter (1942) used the concept of innovations to include both general and specific meanings of technology.

The shift of the production function over time may be specified as

\[ Y = F(X_1, X_2, X_3, X_4, X_5, X_6) = F(K, L, H_1, H_2, H_3, t) \]  \hspace{1cm} (1.1)

where \( Y \) is output and \( X_i \) are the various inputs or sources of productivity, e.g., physical capital (\( K \)), labor (\( L \)), human capital (\( H_1 \)), R&D expenditure (\( H_2 \)), externalities in the form of knowledge diffusion (\( H_3 \)) and the time trend (\( t \)). Denoting time derivatives by a dot over a variable, one could express output growth over time as

\[ \dot{Y} = \frac{dY}{dt} = \sum_{i=1}^{6} F_{X_i} \dot{X}_i = F_k \dot{K} + F_L \dot{L} + F_{H_1} \dot{H}_1 + F_{H_2} \dot{H}_2 + F_{H_3} \dot{H}_3 + F_t \]  \hspace{1cm} (1.2)

where \( F_{X_i} = \frac{\delta F}{\delta X_i} \) denotes marginal productivity of each input. Solow’s technical progress considers a rise in \( \dot{Y} \) due to time alone, i.e., it is a residual after growth accounting due to \( K, L, H_1, H_2 \) and \( H_3 \):

\[ F_t = \dot{Y} - (F_k \dot{K} + F_L \dot{L} + F_{H_1} \dot{H}_1 + F_{H_2} \dot{H}_2 + F_{H_3} \dot{H}_3) \]  \hspace{1cm} (1.3)
The other case of output growth may be due to innovation in the form of R&D investment when $F_{H_2}$ rises, other things being equal.

By Duality any production frontier implies the existence of a cost frontier. Hence a steady state decline of unit costs of output may be caused by a rise in technological progress – either embodied in the various inputs, or, as a residual.

Consider an industry with two groups of firms represented by $y_1(t)$ and $y_2(t)$, where the first group alone exhibits technological progress. Then the unit cost $c_1(t)$ for firm 1 may be represented as

$$
\dot{c}_1(t) = c_1(t) [a - b_1 k_1(t) - b_2 k_2(t)]
$$

(1.4)

where $k_i(t)$ may for instance denote R&D efforts by firms $i = 1, 2$. The fixed costs of R&D efforts may be written as a strict convex function

$$
C(k_i(t)) = (b_3/2)k_i^2(t)
$$

with all the parameters $a, b_1, b_2, b_3$ assumed to be positive. Here the parameter $b_2$ measures the positive technological spillover that firm 1 receives from the R&D effort exerted by firm 2, denoted by $k_2(t)$. The spillover externality is also denoted by $H_3$ in the production function (1.1).

The current profit function $\pi_1(t)$ and its long-run discounted value $J_1(t)$ may be written as

$$
\pi_1(t) = p(t)y_1(t) - (b_3/2)k_1^2(t)
$$

$$
J_1(t) = \int_0^\infty e^{-rt}\pi_1(t)dt
$$

(1.5)

subject to (1.3), where $p(t)$ is the industry demand function which may be linearly written as

$$
p(t) = \alpha_1 - \alpha_2 (y_1(t) + y_2(t))
$$

(1.6)

In the short run, unit costs $c_i(t)$ are constant, so that firms seek to maximize short-run profits $\pi_1$ by choosing the output levels. In the long run however the decline of unit or marginal costs over time is due to increases in R&D efforts $k_i(t)$. Here the firms maximize the long-run discounted profits $J_1(t)$ in (1.14) subject to the dynamic differential equation 1.3.

Clearly, various types of equilibria are possible here, e.g., competitive equilibria, Cournot-Nash equilibria and collusion or cartel or a