4 TECHNOLOGICAL CHANGE AND R&D

This chapter provides background on both production function-based models of technological change and R&D activity. Both topics are critical to an understanding of public/private partnerships.

MODELS OF TECHNOLOGICAL CHANGE

Much of the early literature on technological change stems from production function models in which the output (Q) of a microeconomic unit (a plant, a firm, or even an industry) is represented simply as a function of capital (K) and labor (L):

$$(1) \qquad Q = f(K, L)$$

Of course, there are other inputs in production, such as intermediate materials, services, and financial recourses, but for an initial exposition, a two input model is sufficient.

Following Hicks (1932), so-called Hicksian technological change is defined to be labor-saving, capital-saving, or neutral if the technological change brought about by the adoption of an underlying innovation raises, lowers, or leaves unchanged the marginal product of capital relative to the marginal product of labor for a given capital-to-labor ratio.[1]

[1] Harrod's (1948) classification scheme is similar to that of Hicks except that the capital-to-output ratio is assumed constant rather than the capital-to-labor ratio. Solow's (1967) classification is similar to Harrod's except that the labor-to-output ratio is assumed constant. See Link (1987) and Link and Siegel (2003) for a complete and mathematical overview of the production function concept of technological change.

Using the early production function models of technological change—or more accurately models of the classification of technological change because none of the models addressed the source of the innovation that brought about the technological change—Solow (1957) advanced the concept of an aggregate production function and illustrated it assuming that the function was Cobb-Douglas in nature:

(2) $$Q = A(t)\, K^{\alpha} L^{\beta}$$

where, assuming perfect competition and constant returns to scale, α and β ($\alpha + \beta = 1$) are the shares of income distributed to capital and labor respectively. From equation (2) it follows that the impact of technological change on production can be approximated as a residual growth rate measured as the percentage change in output less the percentage change in capital and labor. This Solow residual is often referred to as the percentage change total factor productivity (TFP), or simply productivity growth, and, based on equation (2), it is often denoted as $\acute{A}/A$.[2]

Since the early 1960s, researchers have engaged in empirical analyses to estimate the impact of investments in R&D on productivity growth under the implicit assumption that R&D is an input into innovation and innovation leads to technological change as measured by the growth in TFP.

For reference, TFP for the U.S. private non-farm business sector for the years 1948 through 2002 is shown in Figure 4.1. This figure will be referred to in later chapters because a number of public policy innovation initiatives were promulgated in response to slowdowns in TFP (in the early and mid-1970s and early 1980s).[3]

Conceptualizing the production function in equation (1) at the firm level, and introducing the firm's stock of technical capital, T, as a third input, the model becomes:

(3) $$Q = A(t)\, F(K, L, T)$$

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[2] $\acute{A}$ denotes the time rate of change in TFP and thus $\acute{A}/A$ denotes the percentage rate of change in TFP.

[3] These data, as noted in Figure 4.1 come from the Bureau of Labor Statistics. The term the Bureau uses is multifactor productivity as opposed to total factor productivity.