

# Economic Theories of Technology

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## 1. Introduction

Technology is a key factor shaping economic growth, and the changes in growth rates. Obviously, this on itself is something that evolutionary economics has in common with the new growth theory. What is special for evolutionary economics, however, is the question how technological change adds to the variability of trend growth rates signaled in point 1. In order to answer this question, two issues seem to be relevant. The first is the distinction between radical and incremental innovation. Radical innovations open up new possibilities for long-run changes in the trend rate of economic growth. When radical (or basic) innovations occur, they disrupt the existing economic structure and dependencies in the economy. This leads to changes in the growth rate that are (again) hard to predict in a detailed way *ex ante*. Incremental innovations are associated with the diffusion of the radical innovations throughout the economy, and they depend crucially on the specific historical and institutional context. The second issue is the (stylized) distinction between innovation and imitation. Technology cannot be fully appropriated by the firm that develops an innovation. In time, technological knowledge spills over to other firms and other nations. While innovation (the development of new technology) may lead to divergence between firms or nations, imitation tends to erode differences in technological competencies, and hence lead to convergence. When diffusion of innovations takes time, and depends on 'fuzzy' institutional factors such as those mentioned above, the exact mix between innovation and diffusion may lead to turbulent growth paths (Silverberg and Verspagen, 1995) provide a quantitative model that illustrates this point).

Embedded in this conceptualization of entrepreneurship is the notion of an innovative process, one perhaps as simple as the perception of new technology adopted from others so as to increase agricultural yield, or one as refined as the actual development of a new technology to do the same. When the process is completed, and when the innovation is put into use, there will be an increase in productivity, and possibly, substitution of capital for labor. We have defined entrepreneurship as a process: an output is the promotion of one's own innovation or the adoption of another's innovation. The term entrepreneurship is commonly used to refer to a businessman or even to a risk taker. We use the term entrepreneur in a much broader sense; an entrepreneur is one who perceives an opportunity and has the ability to act upon it. Hence, entrepreneurship is a process that involves both perception and action. The perception of the opportunity may be influenced by changes in strategic directions or competitive markets, but perception of the opportunity is the fundamental first step. The consequent step is the ability to act on that perception. What defines the entrepreneur is the ability to

move technology forward into innovation. The technology may be discovered or developed by others. The entrepreneur is able to recognize the commercial potential of the invention and organize the capital, talent, and other resources that turn an invention into a commercially viable innovation. What are the requisite resources needed for action, which takes the perception of an opportunity forward to result in an innovation? One obvious answer is research and development (R&D), that is, the commitment of resources to invention and innovation. R&D not only provides a stock of knowledge to encourage perception but also the ability for the firm to foster action. However, firms that do not conduct R&D can still be entrepreneurial, as discussed above. In such firms, innovations are likely to be introduced rather than produced. Such firms act in an entrepreneurial manner by hiring creative individuals and providing them with an environment conducive for the blossoming of their talents (Petit, 2000).

Thus, the role of R&D in enhancing the absorptive capacity of the firm goes beyond simply assessing the technical merits of potentially purchasable technology. It allows the firm to interpret the extant technical literature, to interface when necessary with the research laboratories of others, in a research partnership relationship, or to acquire technical explanations from, say, a federal laboratory or university laboratory; or simply to solve internal technical problems.

Neoclassical theory contends that the particular set of institutions in an economy does not matter. This position rests on three points:

- (a) outcomes are determined by fundamental forces (reflecting resources, preferences, and technology),
- (b) these forces lead to Pareto-efficient outcomes, and
- (c) institutions do not even influence the choice of the equilibrium. For example, whether a society has an institution in which the bride's family pays a dowry, or the groom's family pays a bride price, or neither one, neoclassical theory would contend that—with given fundamentals—the distribution of incomes will be the same as it would have been without those institutions (OECD, 2000). The standard modeling technique in neoclassical economics is to solve for the outcomes that would emerge from an impersonal setting with a market for all goods, all periods, and all risks, where people make trades "with the market." Not even the distribution of wealth matters if one is interested solely in efficiency. These are strong hypotheses. And in leaving out institutions, history, and distributional considerations, neoclassical economics leaves out the heart of development economics. Modern

economic theory argues that the fundamentals are not the only deep determinants of economic outcomes. Neoclassical growth models suggest that markets are basically of extremely competitive nature and that they do not aspire to create a monopoly. Due to this fact, market processes, as a rule, lead to optimal allocation of production factors and maximum production. In addition, these models see little opportunity for the state to promote economic growth. There are at least two conceptual shortcomings of this approach.

First, the neoclassical framework makes it impossible to analyse the determinants of technological changes, which depend entirely on the decisions of economic agents.

Second, neoclassical theory failed to explain the huge differences in growth rates in countries with similar technological development (Todaro, Smith, 2011). In short, neoclassical growth theory failed to explain the essence of emergence of the broadest diffusion of technological changes, and did not manage to, in an acceptable manner, quantify the contribution of this category to production growth at the national level. Although the technology is a central component of neoclassical theory, it remained unmodelled. Technological improvements are introduced exogenously, which leaves differences in the level of technology among countries unexplained (Dragutinović et al., 2015, p. 167). Although neoclassicists identified technological changes as the major source of economic growth and differences in economic development levels of countries, thus permanently indebting macroeconomic theory and policy, they, to tell the truth, did not offer specific practical solutions for achieving technological progress. In particular, they failed to do so bearing in mind the countries at low level of technological and economic development (Švarc, 2009, p.50).

## 2. "Big Push" Theory

This version of the big push theory focuses on the problem of search in the labor market. The productivity of training depends on the ability of trained labor to find employers who have innovated; this ability, in turn, depends on the proportion of firms in the economy that have innovated. To capture this idea, we sketch a simple version of the model of Acemoglu (1997). There are two types of actors: firms, which may adopt new technology or not, and workers, who may become trained to use the new technology or not. The numbers of firms and workers are large and equal, and each firm employs just one worker. There are two time periods. In the first period each firm is matched with one worker; they jointly make decisions about training and innovation, and there is complete contracting between them, that is, there are no information problems or transaction costs. At the end of the first period there is some risk of separation. If separation occurs, a firm has to find a new worker, and a worker has to find a new firm. In the second period, output is produced. If the worker is trained and his firm is one that has adopted new technology, the value of joint output is increased by  $\alpha$ . Skills and technology are assumed to be strongly complementary, so that if either training or innovation does not occur, there is no payoff to skills or to new technology (Siegel, 1999).

## 3. Solow Model

The Solow approach remains the first economic growth model that students learn, usually presented with a focus on the rise in capital per person as the prime force in raising living standards over time. Yet Solow showed that when the saving rate rises in an economy, this leads to a temporary increase in the rate of capital accumulation and a permanent increase in the level of output per capita, but not to a rise in the long-run rate of growth of output per capita. The long-term economic growth rate in Solow's model is actually independent of the rate of saving and capital accumulation. Indeed, in order to produce a sustained rate of growth in his model, Solow had to go beyond mere capital accumulation. He had to introduce an exogenous rate of improvement in labor productivity, presumably the result of technological advancement. But in his famous model, Solow did not try to explain the source of that technological advancement; he merely assumed it (Tassey, 2000).

Understanding long-term economic growth requires understanding technological innovation. The technically challenging part of the Solow growth models lies in solving a differential equation for how fast the capital stock grows rather than in interpreting the mysterious process of technological change. And so, for the many years following Solow's initial contribution economists studied the role of savings and investment as the central feature of economic growth, rather than focusing on the sources of long-term technological change.

Training imparts to the worker skills that he can use with any firm that has adopted the new technology. Therefore, if there were no search costs in the labor market, separation between a firm and an employee would not create a loss: if separation occurred, the worker would simply move on to another firm that had adopted the new technology, and all the surplus from training and investment would be captured by the firms and workers that made the investments. But suppose that search is costly. Then matching will be imperfect. There is no guarantee that the firm with the investment in the new technology will be matched with the worker who has the training (Romer, 2000).

Endogenous growth theory indicates an attempt to explain the long-term growth of the developed countries (Baro, 2004). Essentially, an endogenous approach to the research of economic growth is based on econometric analysis, which includes a number of variables and quantifies their impact on economic growth (Sala-i-Martin, 1997, p. 178). The key postulate of endogenous growth theory is the elimination of the premise of diminishing returns on production factors. This creates the conditions for the growth of production per worker without limitations. "Under this assumption, endogenous growth models do not imply the likelihood of convergence, or reaching the steady-state growth equilibrium, having in mind that endogenous variables are determined within the economic model, and exogenous variables are taken as the given ones in the analysis of the economic model" (Dosi, 1982). There is a large number of divisions of endogenous growth models. One of them is their classification into: a) endogenous models based on externalities, b) models based on research and

development activities, and c) the so-called AK models (Grossman, 1966). The most prominent authors of the models within the framework of the three groups are given in Table 1. The first row relates to predecessors of a certain group of endogenous growth models. In light of the defined subject and purpose of the research, it is certain that the most important are a) endogenous growth models based on externalities in the form of technological spillover (Romer, 1986) and b) growth models based on activities of applied research and development (Romer, 1990; Aghion, Howitt, 1992; Grossman, Helpman, 1991).

Another group of growth models, which stress the importance of the category of technological changes, are the models based on the activities of applied research and development. Building on some Schumpeter's ideas (1961), Romer developed the first model of sustainable growth that can be classified in this model group (Romer, 1990), and was followed by Agion and Howitt (1992), Grossman and Helpman (1994). Endogenous growth models in this group imply the existence of monopolistic structures, power, and the existence of a separate research sector in the economy, which, in a unique way, supplies other sectors with technology. By purchasing the new technology, manufacturers gain the legal right to its use. The price charged is higher than the marginal cost of production, to generate income sufficient to cover the costs caused by large initial investment in creating new technological solutions. Investment in innovation projects, in this regard, is not characterised by diminishing returns. Therefore, the productivity of new investment in innovative activity is not reduced, which is in the function of sustainable economic growth. In these model presentations, the growth rate depends on the amount of funds intended for research and development activities, the degree to which new technology can be used privately (degree of monopoly power), as well as the time horizon of investors.

The endogenous theory points to the importance of the institutional framework for stimulating innovation, as motivation for innovation depends on the ability of innovators to commercialise innovation. In recent decades, due to the popularity of endogenous growth theory, economists increasingly believe that differences in innovation capacity are largely responsible for large differences in development levels of individual economies (Grossman, Helpman 1991, pp. 46-51). In endogenous growth models, the adequately defined higher level of investment does not only increase the per capita income, but may sustain high and rising growth rates in the future. This means that it is possible that countries continue to grow rapidly for a long period, even when they have already achieved a relatively high income per capita. There is no targeted equilibrium income level determined by the factors of production used. What is more, there is no predetermined maximum level of income that can be achieved on the basis of savings rates and limits of diminishing returns.

#### 4. Conclusion

The key drivers of technological changes in endogenous explanations are knowledge, research and development, and education. These factors, just like standard production factors, labour and capital, create new value. They rely on the expression of external effects, i.e. allow for non-diminishing returns on production factors at the aggregate level. In this way, endogenous models conceptually removed the key shortcoming of neoclassical theories, according to which economic growth, in the absence of technology shocks, tends towards zero growth. Evolutionary-institutional theories attempt to overcome simplification of neoclassical growth models, especially in terms of their treatment of technological changes as a category outside the production function. According to evolutionary growth theorists, there are internal forces that drive the category of technological changes, and, more importantly, which can be stimulated through conscious control activity of the state.

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