TECHNOLOGY, R&D, AND EFFICIENCY

STUDY GUIDE

A market economy is not static but subject to change over time. One dynamic force affecting an economy and industries is **technological advance.** This advance occurs over a very long time and allows firms to introduce new products and adopt new methods of production.

The chapter begins by discussing the three-step process that constitutes technological advance: **invention, innovation,** and **diffusion.** Here the text describes many real-world examples of how technological change has affected firms and industries. You will also find out that research and development (R&D) expenditures by firms and government play an integral role in directly supporting this technological advance. The traditional view of economists was that technological advance was something external to the economy, but most contemporary economists think that technological advance is integral to capitalism and arises from intense rivalry among firms.

Entrepreneurs and other innovators play a major role in encouraging innovation and technological change. Entrepreneurs typically form small companies—**start-ups**—to create and introduce new products and production techniques. In this activity entrepreneurs assume personal financial risk, but if they are successful, they can be highly rewarded in the marketplace. There also are innovators within existing firms who can use R&D work to develop new products. University and government research also can contribute output that can be useful for fostering technological advance.

A major section of this chapter analyzes how the firm determines the **optimal amount of R&D spending.** The decision is made by equating marginal benefit with marginal cost. The marginal cost is measured by the interest-rate cost of funds that the firm borrows or obtains from other sources to finance its R&D expenditures. The expected rate of return from the last dollar spent on R&D is the measure of marginal benefit. You should remember that the outcomes from R&D spending are only expected, not guaranteed, for the firm.

Technological changes can increase a firm's profit in two ways. Recall that profit is simply the difference between total revenue and total cost. **Product innovation** can increase revenues because people buy more products from the innovative firm. These increased revenues will increase profits, assuming that costs stay the same. **Process innovation** also can increase profits by reducing costs. This type of innovation leads to better methods for producing a product and decreases the average total cost for the firm.

One problem with technological advance is that it encourages **imitation.** Successful innovative firms often are emulated by others. This imitation problem can be especially threatening to innovative, smaller firms because the dominant firms in the industry can challenge them. A firm, however, has some advantages in taking the lead in innovation because there are protections and rewards. Legal protections include patents, copyrights, and trademarks; other advantages are early brand-name recognition or the potential for a profitable buyout.

You spent the past three chapters learning about the differences in the four market structures. Now you may be wondering whether one market structure is better suited than another for encouraging technological progress. The answer is clearly mixed because each structure has its strengths and shortcomings. The **inverted-U theory of R&D** gives you an even better framework for figuring out the optimal industry structure for R&D.

The chapter ends by returning to the issue of **economic efficiency,** a topic discussed throughout the text. Technological advance has a double benefit because it enhances both productive efficiency and allocative efficiency. Productive efficiency increases from process innovation that reduces production costs. Allocative efficiency increases because product innovation gives consumers more choice and gives society a more desired mix of products. The efficiency results are not automatic, and the outcome may depend on whether innovation strengthens or weakens monopoly power.

■ CHECKLIST

When you have studied this chapter you should be able to

- Define technological advance.
- Describe each of the three steps in technological advance.
- Explain the role of research and development (R&D) in technological advance.
- Contrast the traditional with the modern view of technological advance.
- Distinguish between entrepreneurs and other innovators and between start-ups and innovation in existing firms.
- Explain how innovators are rewarded for anticipating the future.
- Describe the role that universities and government play in fostering technological advance.
- Identify five means for financing R&D that are available to firms.
- Describe and give a rationale for the interest-rate cost-of- funds curve and the expected-rate-of-return curve.
- Show graphically with an example how the optimal level of R&D expenditures is determined.
- State three important points from the analysis of optimal R&D expenditures.
- Explain how product innovation can increase profits by increasing revenues.
- Describe how process innovation can increase profits by reducing costs.
- Explain the imitation problem for firms.
- Identify six protections for or advantages to being the first to develop a new product or process.
- Evaluate which of the four market structures is best suited to technological advance.
- Explain the inverted-U theory of R&D and its implications for technological progress.
- Describe how technological advance enhances both productive and allocative efficiency.
- Explain how innovation may lead to creative destruction and describe the criticisms of this view.

- Discuss the issue of whether the federal government should expand spending on research and development (Last Word).

■ CHAPTER OUTLINE

1. ***Technological advance*** involves the development of new and improved products and new and improved ways of producing and distributing the products. The technological change occurs in the ***very long run.*** It is a three-step process of invention, innovation, and diffusion.
    a. ***Invention*** is the most basic part of technological advance and involves the discovery of a product or process. Governments encourage invention by granting the inventor a ***patent,*** which is an exclusive right to sell a product for a period of time.
    b. ***Innovation*** is the first successful commercial use of a new product or method or the creation of a new form of business. There are two major types: ***product innovation,*** which involves new and improved products or services, and ***process innovation,*** which involves new and improved production or distribution methods. Innovation is an important factor in competition because it can enable a firm to leapfrog competitors by making their products or methods obsolete.
    c. ***Diffusion*** is the spread of an innovation through imitation or copying. New and existing firms copy or imitate successful innovation of other firms to profit from new opportunities or to protect their profits.
    d. In business, research and development (R&D) includes work and expenditures directed toward invention, innovation, and diffusion. Government also supports R&D through defense expenditures and the funding of other activities.
    e. The traditional view of technological advance was that it was external to the economy. It was viewed as a random force to which the economy adjusted and it depended on the advance of science. The modern view is that it is internal to capitalism. Intense rivalry among individuals and firms motivates them to seek and exploit new or expand existing opportunities for profit. Entrepreneurs and other innovators are the drivers of technological advance.

2. The **entrepreneur** is an initiator, innovator, and risk bearer. Other innovators are key people involved in the pursuit of innovation but who do not bear personal financial risk.
    a. Entrepreneurs often form small new companies called ***start-ups,*** which are firms that create and introduce a new product or production technique. Innovators are found within existing corporations.
    b. R&D work in major corporations has resulted in technological improvements, often by splitting off units to form innovative firms.
    c. Innovators attempt to anticipate future needs. Product innovation and development are creative activities with both nonmonetary and monetary rewards. More resources for further innovation by entrepreneurs often come from past

successes. Successful businesses that meet consumer wants are given the opportunity to produce goods and services for the market.

d. New scientific knowledge is important to technological advance. Entrepreneurs study the scientific results from university and government laboratories to find those with commercial applicability.

3. The ***optimal amount of R&D*** expenditures for the firm depends on the marginal benefit and marginal cost of R&D activity. To earn the greatest profit, the firm will expand an activity until its marginal benefit equals its marginal cost.
    a. Several sources are available for financing firms' R&D activities: bank loans, bonds, retained earnings, ***venture capital,*** or personal savings. A firm's marginal cost of these funds is an interest rate *i*.
    b. A firm's marginal benefit of R&D is its expected profit (or return) from the last dollar spent on R&D.
    c. The *optimal amount of R&D* in marginal-cost and marginal-benefit analysis is the point where the ***interest-rate cost-of-funds*** (marginal-cost) ***curve*** and the ***expected-rate-of-return*** (marginal-benefit) ***curve*** intersect. This analysis leads to three important points. First, R&D expenditures can be justified only if the expected return equals or exceeds the cost of financing R&D. Second, the firm expects positive outcomes from R&D, but the results are not guaranteed. Third, firms adjust R&D spending when expected rates of return change on various projects.

4. A firm's profit can be increased through *innovation* in two ways.
    a. The firm can increase revenues through **product innovation.** From a utility perspective, consumers will purchase a new product only if it increases total utility from their limited incomes. The purchases of the product by consumers increase the firm's revenues. Note three other points.
        1. Consumer acceptance of a new product depends on both its marginal utility and price.
        2. Many new products are not successful, so the firm fails to realize the expected return in these instances.
        3. Most product innovations are small or incremental improvements to existing products, not major changes.
    b. **Process innovation,** the introduction of better ways to make products, is another way to increase profit and obtain a positive return on R&D expenditures. It results in a shift upward in the firm's total product curve and a shift downward in the firm's average total cost curve, which increases the firm's profit.

5. The ***imitation problem*** is that the rivals of a firm may copy or emulate the firm's product or process and thus decrease the profit from the innovator's R&D effort. When a dominant firm quickly imitates the successful new product of smaller competitors with the goal of becoming the second firm to adopt the innovation, it is using a ***fast-second strategy.***
    a. Taking the lead in innovation offers the firm several protections and potential advantages from being first to produce a product.
        1. Patents limit imitation and protect profits over time.
        2. Copyrights and trademarks reduce direct copying and increase the incentives for product innovation.
        3. Brand names may provide a major marketing asset.
        4. Trade secrets and learning by doing give firms advantages.
        5. The time lags between innovation and diffusion give innovators time to make substantial economic profits.
        6. There is the potential purchase of the innovating firm by a larger firm at a high price.
    b. *Consider This* (Trade Secrets). Trade secrets have been part of business practices for centuries. This anecdote tells the story of a Roman citizen, Erasmo, who used sheep intestine for violin strings. To protect his secret and keep his monopoly profit, he deceived people by telling them he used catgut, knowing full well that they would not likely use it and become a competitor because killing a cat was considered to be bad luck.

6. Certain market structures may foster *technological advance.*
    a. Each **market structure** has strengths and limitations.
        1. *Pure competition:* Strong competition gives firms the reason to innovate, but the expected rate of return on R&D may be low or negative for a pure competitor.
        2. *Monopolistic competition:* These firms have a strong profit incentive to develop and differentiate products, but they have limited ability to obtain inexpensive R&D financing. It is also difficult for these firms to extract large profits because the barriers to entry are relatively low.
        3. *Oligopoly:* Although the size of these firms makes them capable of promoting technological progress, there is little reason for them to introduce costly new technology and new products when they earn large economic profits without doing it.
        4. *Pure monopoly:* This type of firm has little incentive to engage in R&D because its high profit is protected by high barriers to entry.
    b. ***Inverted-U theory of R&D*** suggests that R&D effort is weak in industries with very low concentration (pure competition) and very high concentration (pure monopoly). The optimal industry structure for R&D is one in which expected returns on R&D spending are high and funds are readily available and inexpensive to finance. This generally occurs in industries with a few firms that

are absolutely and relatively large, but the concentration ratio is not so high as to limit strong competition by smaller firms.

c. General support for the inverted-U theory of R&D comes from industry studies. The optimal market structure for technological advance appears to be an industry with a mix of large oligopolistic firms (a 40 to 60% concentration ratio) and several highly innovative smaller firms. The technical characteristics of an industry, however, may be a more important factor influencing R&D than its market structure.

7. Technological advance enhances *economic efficiency.*
    a. **Process innovation** improves productive efficiency by increasing the productivity of inputs and reducing average total costs.
    b. **Product innovation** enhances allocative efficiency by giving society a more preferred mixture of goods and services.
        1. The efficiency gain from innovation, however, can be reduced if patents and the advantages of being first lead to monopoly power.
        2. Monopoly power can be reduced or destroyed by innovation because it provides competition where there was none.
    c. Innovation may foster **creative destruction,** whereby the creation of new products and production methods simultaneously destroys the monopoly positions of firms protecting existing products and methods. This view is expressed by Joseph Schumpeter, and there are many examples of it in business history. Another view suggests that creative destruction is not inevitable or automatic. In general, innovation improves economic efficiency, but in some cases it can increase monopoly power.

8. *Last Word* (The Relative Decline of Federal R&D Spending). The percentage of the federal budget devoted to basic scientific research dropped from 13.8 percent in 1965 to just 3.9 percent in 2009. Some economists argue that the federal government is spending too much money on current consumption through transfer payment programs such as Social Security, Medicare, and Medicaid and not enough money on this research. This basic scientific research should be thought of as a productivity-enhancing public good with positive externalities. This research takes years for the full value to show and is not likely to be done by private businesses, which focus on shorter-term projects.

■ HINTS AND TIPS

1. The section of the chapter on a firm's **optimal amount of R&D** uses marginal-cost and marginal-benefit analysis similar to what you saw in previous chapters. In this case, the interest rate or expected return is graphed on the vertical axis and the amount of R&D

spending on the horizontal axis. The only difference from previous MB-MC graphs is that the marginal cost in this example is assumed to be constant at the given interest rate. *It is graphed as a horizontal line.* The expected-rate-of-return curve is downsloping because there are fewer opportunities for R&D expenditures with higher expected rates of return than at lower expected rates of return.

2. The explanation for how new products gain acceptance by consumers is based on the marginal utility theory that you learned about in Chapter 7. Be sure to review the text discussion of Table 7.1 before reading about the example in Table 13W.1.

3. When new processes are developed, they can increase a firm's total product curve and decrease a firm's average total cost curve. Review the section in Chapter 9, "Shifts of the Cost Curves," to understand these points.

■ IMPORTANT TERMS

technological advance
very long run
invention
patent
innovation
product innovation
process innovation
diffusion
start-ups
optimal amount of R&D
venture capital
interest-rate cost-of-funds curve
expected-rate-of-return curve
imitation problem
fast-second strategy
inverted-U theory of R&D