LAST WORD

3-D Printers

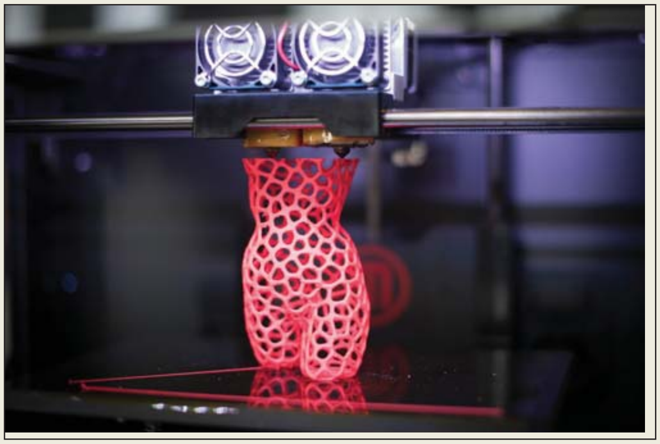
3-D Printers Are Poised to Replace Mass Production with Mass Customization.

Both a billionaire and your Average Joe can buy a pocketknife for $10. They can also both buy an iPhone for $199. And they can both purchase a new compact car for under $15,000.

The fact that all of these items are affordable to both a billionaire and your Average Joe is due to mass production and economies of scale. The iPhone, for instance, is one of the most complicated devices ever made. It contains cutting-edge technologies for graphics, voice recognition, battery length, screen durability, and many other features. Most of those technologies took hundreds of millions—if not billions—of dollars to develop and the factories that manufacture the iPhone and its components themselves cost many billions of dollars to set up. Yet, the iPhone is so inexpensive that Average Joes can afford to buy one.

That mass affordability is the result of mass production coupled with mass sales. Marginal costs are typically quite low with mass production. So if manufacturers can tap mass markets and sell their products in large numbers, they can achieve low per-unit costs by spreading the massive fixed costs (for developing the new technologies and setting up the factories) over many units. Doing so results in economies of scale, low average total costs per unit, and low prices that even average folks can afford.

Mass production and mass sales first became possible during the Industrial Revolution, which began in England during the late 1700s and then spread through most of the rest of the world during the next two centuries. The Industrial Revolution occurred when steam-powered engines became powerful enough to drive factory equipment, propel ships, and pull trains. Engineers and inventors used steam power to automate factories and initiate the low-cost mass production of consumer goods. That process only accelerated when, in the late nineteenth century, the so-called Second Industrial Revolution saw electricity harnessed to drive factories and provide lighting.



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different sizes. The apparel, food processing, furniture, wood products, snowboard, banking, and small-appliance industries are examples. With an extended range of constant returns to scale, relatively large and relatively small firms can coexist in an industry and be equally successful.

Compare this with Figure 9.9b, where economies of scale continue over a wide range of outputs and diseconomies of scale appear only at very high levels of output. This pattern of declining long-run average total cost occurs in the automobile, aluminum, steel, and other heavy industries. The same pattern holds in several of the new industries related to information technology, for example, computer microchips, operating system software, and Internet service provision.

Given consumer demand, efficient production will be achieved with a few large-scale producers. Small firms cannot realize the minimum efficient scale and will not be able to compete. In the extreme, economies of scale might extend beyond the market's size, resulting in what is termed **natural monopoly,** a relatively rare market situation in which average total cost is minimized when only one firm produces the particular good or service.

Where economies of scale are few and diseconomies come into play quickly, the minimum efficient size occurs at a low level of output, as shown in Figure 9.9c. In such industries a particular level of consumer demand will support a large number of relatively small producers. Many retail trades and some types of farming fall into this category. So do certain kinds of light manufacturing such as the baking, clothing, and shoe industries. Fairly small firms are more efficient than larger-scale producers in such industries.

Our point here is that the shape of the long-run average-total-cost curve is determined by technology and the economies and diseconomies of scale that result. The shape of the long-run ATC curve, in turn, can be significant in determining whether an industry is populated by a relatively large number of small firms or is dominated by a few large producers, or lies somewhere in between.

But we must be cautious in our assessment because industry structure does not depend on cost conditions alone.

Mass sales, however, are not easy. They require large distribution networks, massive advertising budgets, and, perhaps most important, cheap ways of shipping products from factories to consumers. Thus, it was crucially important that transportation was also vastly improved during the First and Second Industrial Revolutions. If not for better ships, smoother roads, and cheap transportation by railroad, transportation costs would have been so high that consumers would not have been able to afford mass-produced products shipped from distant factories.

Now, a new technology promises to deliver a Third Industrial Revolution that will feature not only low production costs but also zero transportation costs. Even better, both of those highly attractive features will be possible *even if you make only a single unit of a product.* In addition, each unit can be fully customized to a consumer's wants and needs. As a result, our world of affordable mass production may soon be replaced by a world of affordable mass customization.

The new technology is called additive manufacturing and it creates objects using computer-controlled devices known as "3-D printers." The 3-D (three-dimensional) printers contain a fine powder of metal or plastic particles that sit in a bin. A laser moves rapidly over the powder, the heat of its beam fusing small clumps of the powder together. Guided by a computerized blueprint, the rapidly moving laser can fuse a single layer of a complicated object together in just a few seconds.

The bin is then lowered a bit, another layer of powder is placed on top, and the laser again begins to shoot, this time fusing together both the previous layer as well as the current layer. Doing this over and over, one layer atop another, results in a solid object whose shape is limited only by the complexity of the blueprint. Any of the powder that is not struck by the laser and incorporated into the object is simply recycled for later use.

Because 3-D printers are inexpensive, they could potentially be located anywhere. Thus, there is no need to worry about transportation costs since objects could be manufactured by consumers in their own homes or in local workshops located only a short drive away. And because the powders are cheap and the machines only require a modest amount of electricity, anything that could be made using a 3-D printer would be inexpensive even if you were only making a single unit.

The First Industrial Revolution delivered low prices by spreading massive fixed costs over many units. The Third Industrial Revolution is set to deliver even lower prices by eliminating two types of costs—the massive fixed costs necessary to set up large factories and the transportation costs needed to ship resources to factories and then finished goods to consumers.

One major cost might still remain, however. That is the cost of paying people to make the blueprints that drive the 3-D printers. But just as digital file sharing has pushed the price of recorded music toward zero, many analysts suspect that digital file sharing will also drive the price of blueprints very low. If so, the cost of manufactured goods may soon plunge to levels even lower than what has been achieved through mass production.

So far, only relatively simple objects can be made with 3-D printers. But some engineers see a day in the not-so-distant future when it may be possible to create even complicated devices like an iPhone using additive manufacturing. If so, people will simply download inexpensive blueprints, make a few changes to customize the product, and then "print" what they want.

Government policies, the geographic size of markets, managerial strategy and skill, and other factors must be considered in explaining the structure of a particular industry.

QUICK REVIEW 9.3

- ✓ Most firms have U-shaped long-run average-total-cost curves, reflecting economies and then diseconomies of scale.
- ✓ Economies of scale are the consequence of greater specialization of labor and management, more efficient capital equipment, and the spreading of start-up costs over more units of output.
- ✓ Diseconomies of scale are caused by the problems of coordination and communication that arise in large firms.
- ✓ Minimum efficient scale (MES) is the lowest level of output at which a firm's long-run average total cost is at a minimum.

Applications and Illustrations

LO9.5 Give business examples of short-run costs, economies of scale, and minimum efficient scale (MES).

The business world offers many examples relating to short-run costs, economies of scale, and minimum efficient scale (MES). Here are just a few.

Rising Gasoline Prices

As we discuss in the appendix to Chapter 3, changes in supply and demand often lead to rapid increases in the price of gasoline. Because gasoline is used to power the vast majority of all motor vehicles, including those used by businesses, increases in the price of gasoline lead to increases in firms' short-run variable costs, marginal costs, and average total costs. In terms of our analysis, their AVC, MC, and ATC curves all shift upward when an increase in the price of gasoline increases production costs.

The extent of these upward shifts depends upon the relative importance of gasoline as a variable input in the various firms' individual production processes. Package-delivery companies