Making More Out of Less: The Recipe for Long-Term Economic Growth

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References to the pace of economic growth in the United States and elsewhere are commonplace in the news media. However, it's much less common to find informed discussions of the forces that shape the economic growth of nations. This article describes the salient facts gathered by economists on the sources of economic growth in the United States and other countries. Although these facts do not cover every aspect of this complex phenomenon, they do shed considerable light on the mainsprings of economic growth and on the kinds of growth-related government policies that might prove beneficial to the economy.

The phenomenon of economic growth has many aspects, but the central one is that the real value of output produced by an hour's work in the U.S. has risen over the years: in 1991, the value of output for an hour of work was about twice the value of output for an hour's work in 1950 (Figure 1). This increase in productivity or in the economic worth of work-time is the hallmark of economic growth. The question to which we seek an answer is: what are the main reasons for increases in productivity? The key parts of the answer are an increase in the amount of capital used by each worker and technical progress.

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SOURCES OF GROWTH IN OUTPUT PER HOUR WORKED

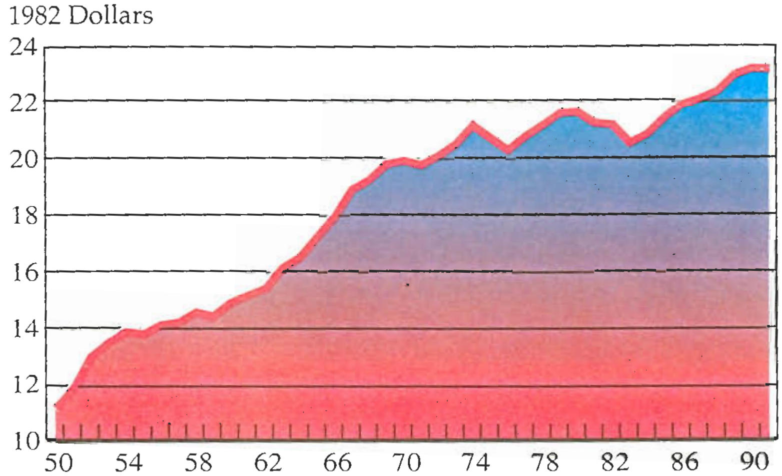
Economists approach the question of the sources of economic growth by relating the total value of output produced per hour to variations in the use of the two primary factors of production: labor-time and the capital stock. Since these terms will have specific meaning in this article, it's best to begin by defining what they mean.

Labor-time means the total amount of time, say, in a year, that members of a nation spend in the production of goods and services valuable to households and firms. In principle, it includes the total time spent earning a living (through honest means!) and also the total time spent doing chores around the house. Since measuring the time spent on housework is difficult, the practical definition of labor-time (and the one that we will use) is the time spent in the production of goods and services for the marketplace and in the production of government services.[1]

Capital stock means the vast stock of every kind of building, structure, and machinery used in conjunction with labor-time. It includes all factories and office buildings and the equipment therein, as well as infrastructure: facilities such as roads, railroads, bridges, canals, harbors, and docks. This enormously diverse collection of man-made things can be measured only in terms of its total economic or monetary value. Therefore, the capital stock of a nation means the monetary value of all the buildings, structures, and machinery used in conjunction with labor-time.

FIGURE 1

Output per Hour Worked 1950 - 1991



How, then, might variations in labor-time and the capital stock explain variations in output per hour? As an extreme but illuminating example, consider how a building is constructed in the United States versus how one is constructed in a country like India. In the United States, a construction worker has at his disposal a large array of sophisticated tools: pneumatic drills, jackhammers, electric screwdrivers, forklifts, cranes, and all kinds of heavy earth-moving equipment to help carry out the building tasks. In contrast, a construction worker in India works with nothing more than ordinary hammers, chisels, and shovels. As a result, if the construction of a similarly sized building is to be completed in the same amount of time, the number of construction workers needed for the job in India will be many times that needed in the United States. More generally, the number of hours of work needed on a building will be much greater in India than in the United States. If the economic value of the

[1]Similarly, the measure of national output should, in principle, include the monetary value of the work done around the house. However, because of the difficulty of constructing such a measure, the value of housework is excluded from official estimates of national output.

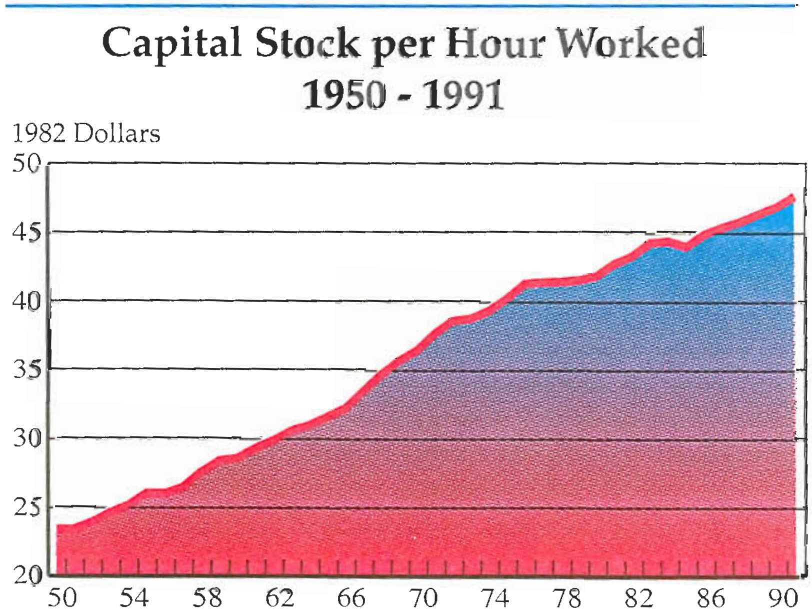
building is the same in both countries, the value of output produced per hour of work will be much lower in India than in the United States, i.e., the productivity of the Indian construction worker is a fraction of the productivity of the American construction worker.

It should be clear why this is the case. An American construction worker is assisted by more capital stock than an Indian construction worker: the dollar value of pneumatic drills, jackhammers, electric screwdrivers, forklifts, cranes, and heavy earth-moving equipment used in the U.S. is many times larger than the dollar value of hammers, chisels, and shovels used in India. In other words, one important reason why productivity in the American construction industry is so much higher than in the Indian construction industry is that the capital stock used per hour of work (the capital-labor ratio, as economists call it) is much higher in the United States than in India.

What is true of India and the United States today is also true, in less extreme form, of the United States of 1950 and the United States of today. Measurements of the U.S. capital stock reveal that capital stock per hour worked has risen over the years (Figure 2). From this increase in the capital stock per hour of work, we should expect productivity to be higher in 1991 than in 1950. A natural question is: is the increase in capital stock per hour worked the sole factor, or even the most important factor, underlying the economic growth of the United States?

In the mid-1950s, several American economists attempted to answer this question for the United States. Moses Abramovitz (1956), John Kendrick (1956), and Robert Solow (1957) examined historical data on national output per hour worked and the stock of tangible physical capital per hour worked to see if increases in the capital stock per hour worked were the dominant factor driving U.S. economic growth. In perhaps the most well known of these studies, Robert Solow calculated the annual percentage change in national output per hour worked and capital stock per hour worked for the 1909-1949 period. To complete his calculations he needed to know how much a 1 percent increase in the capital stock per hour worked would increase output per hour. He observed that over this period the owners of capital received about 36 percent of national income (the rest being payment to labor), which suggested that, on average, the capital stock contributed 36 percent of the total output of the economy. With this in mind, Solow concluded that a 1 percent increase in the capital stock per hour worked would raise output per hour by 0.36 percent. Using this estimate of the contribution of capital stock to national output, Solow discovered that growth in capital stock per hour worked accounted for less than 15 percent of the increase in national output per hour worked over

FIGURE 2



this period. Moses Abramovitz, who used the same methodology for the period 1870 to 1953, found that increases in capital stock per hour worked accounted for only 14 percent of the increase in national output per hour worked over this period. In other words, an astonishing 85 percent of the total economic growth over the 80-odd years beginning in 1870 appeared to be caused by factors other than an increase in the capital stock per hour worked!

What else could be contributing to economic growth? Let's go back to the comparison between the American and the Indian construction worker. While it's true that the dollar value of the tools that the American worker has at his disposal is much greater than the dollar value of the tools at the disposal of the Indian worker, it's not merely the case that the American worker has *more* of the *same* tools than the Indian worker. There's a clear qualitative difference between a bulldozer and a shovel, although both are used to move soil. In other words, the higher dollar value of capital stock per hour worked in the United States is also associated with a superior construction technology. Similarly, superior technology also accompanies the larger capital stock per hour worked in 1953 relative to 1870, and output per hour worked would be higher in 1953 on this count as well. Robert Solow made the bold suggestion that technical progress explained the remaining 85 percent of economic growth.

Technical progress makes any given dollar-value increase in the capital stock per hour worked more effective in generating additional output, or, conversely, it allows any given increase in national output to be attained with less of an increase in capital stock per hour worked (which might mean less capital or less labor-time or both). This increase in output per hour worked due to technical progress is called an increase in *total factor productivity* (TFP).[2]

The quantitative importance of TFP growth in accounting for U.S. economic growth over the period 1870-1953 proved to be a phenomenon that cut across national boundaries and particular histories. Edward Denison's well-known study of the U.S. and eight European countries for 1950-1962 shows that TFP growth was by far the most important source of growth in national output (Table). For these countries, its contribution is never below 64 percent (U.S.) and reaches as high as 86 percent (Germany).[3]

We can plot the advance of TFP in the United States during 1950-1991 (Figure 3). The top line is the level of output per hour worked in the U.S and is the same line that appears in Figure 1. The lower line shows the level of output per hour worked that would have been attained if TFP had remained at its 1950 level; its rise is solely the result of the increase in capital stock per hour worked. Thus, the gap between the two lines is a measure of how much the level of output per hour worked owes to increases in TFP.

While the Table and Figure 3 display the importance of TFP growth in accounting for growth in national output, they understate its importance as a causal factor. According to Solow (1956), the reason is that capital stock per hour worked grows partly in response to an

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[2]The use of the term "TFP growth" rather than "technical progress" partly reflects the controversy that followed Solow's suggestion that technical progress accounted for the unexplained growth in output. At that time, many economists were unconvinced that technical progress was the key to the unexplained growth in output per hour worked. Hence, they adopted the more neutral term, TFP growth. Since the 1950s, however, numerous authors have shown that a large portion of the unexplained growth in output can be accounted for by careful measurements of the improvements in the quality of labor-time and capital stock (see, for instance, Maddison, 1987). Since improvements in the quality of inputs is an aspect of technical progress, Solow's suggestion stands vindicated.

[3]Denison, unlike Solow, measured labor input by the number of persons employed rather than total hours worked. However, since he adjusted his figures for changes in the average number of hours worked by a person, this difference is unimportant.

TABLE

Country	Growth Rate of National Output per Person Employed (1950-62)	The percentage contribution of	
		TFP	Capital per Person Employed
United States	2.15	64	36
Belgium	2.64	75	25
Denmark	2.56	74	26
France	4.80	75	25
Germany	5.15	86	14
Holland	3.65	75	25
Italy	5.36	80	20
Norway	3.27	74	26
United Kingdom	1.63	74	26

Source: Adapted from Tables 21-2 to 21-20 in Edward F. Denison: *Why Growth Rates Differ*, Washington, D.C.: Brookings Institution, 1967.

increase in TFP: as advances in technology make labor and capital more productive, firms exploit the increase in TFP by investing in newer and better buildings, structures, and equipment. In other words, growth in capital stock per hour worked is never an entirely *independent* factor contributing to economic growth: part of the growth in a nation's capital stock per hour worked occurs to keep pace with increases in its TFP.

Is there a way to tell how much of the increase in capital stock per hour worked occurs in response to increases in TFP and how much of it occurs for other reasons? Solow pointed out that if a nation's capital stock per hour worked rose in response to factors other than an improvement in TFP, the percentage increase in national output per hour worked would be only 0.36 of the percentage increase in capital stock per hour worked, so that the *ratio* of capital stock per hour worked to output per hour worked would rise. In contrast, if capital stock per hour worked rose in response to an increase in TFP, the capital-to-output ratio need not rise because of the added effect of higher TFP on output per hour worked. For the United States the ratio of capital to output has remained roughly constant, suggesting that capital accumulation in the U.S. has largely been in response to increases in TFP.[4] Also, capital-output ratios are observed to be roughly constant as well for the European countries examined by Denison. Thus, increases in TFP have been the single most important factor driving economic growth in these countries. In short, the human ability to make more out of less is at the heart of economic progress.

DETERMINANTS OF TFP GROWTH

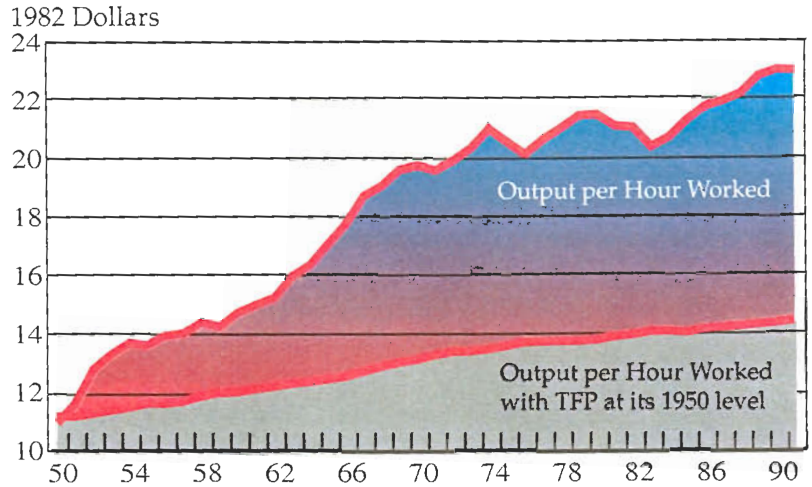
Inventions. Inventing new products or new ways to make old products accounts for one of the primary sources of TFP growth in industri-

[4]To state this point differently, if capital stock per hour worked rose without an accompanying increase in TFP, diminishing returns to capital would cause the output-capital ratio to fall. For the United States, the fact that the capital-output ratio has remained constant in the face of growing capital stock per hour means that a continuous rise in TFP has offset the force of diminishing returns. In Solow's growth model, a steady increase in TFP stimulates firms to raise the capital stock per hour and, by simultaneously increasing household income, also provides the resources to finance this accumulation. Output and capital stock grow together at a rate equal to the growth rate of TFP, and thus the capital-output ratio remains constant.

alized countries. Each of these activities makes labor and capital more productive, although for somewhat different reasons. An improved process for making an existing product directly enhances productivity by economizing on labor and capital or on intermediate inputs such as raw materials and energy. A new product improves productivity indirectly by drawing away labor and capital from less valuable uses, thereby enhancing the value of goods and services produced by existing amounts of labor and capital.

FIGURE 3

Growth in TFP
1950 - 1991



In light of the international differences in TFP growth evident in the Table, an important issue is whether the pace of inventions in a country is related to the amount of resources it expends on inventive activity.

Zvi Griliches and Ariel Pakes (1984) studied the correlation between the research and development (R&D) expenditures of large U.S. firms and the number of patents issued to them each year. They found that the quantity of patents issued yearly to different firms was positively and strongly related to the level of R&D expenditures in that firm: firms that spent more on R&D generated more patents, on average.

However, all patents are not equally valuable, and not all inventions are patented. To make a more compelling case for the potency of R&D expenditures, it's necessary to examine its correlation with firm-performance measures such as the market value of common stock. Ariel Pakes (1985) documented a positive correlation between companies' expenditures on R&D and their stock value. Since many other factors besides the outcome of R&D efforts affect stock value, the correlation found is naturally not as strong as that between R&D and patents. Nevertheless, there's enough evidence to suggest that R&D expenditures generate valuable inventions for firms. Also, Saul Lach and Mark Schankerman (1989) and Saul Lach and Rafael Rob (1992) have shown that firms and industries that spend more on R&D also tend to spend more on equipment and machinery in future periods, which suggests that spending on R&D does generate profitable investment projects.

Therefore, at least for the U.S., evidence shows that the rate of TFP growth is influenced by the level of R&D expenditures. Nevertheless, this influence is imperfect because the outcome of R&D efforts involves a substantial amount of randomness. Also, as John Bound and associates (1984) document, many firms that generate patents do not report any significant R&D expenditures, perhaps because many inventions do not arise from directed R&D efforts but happen simply because individuals think up improvements in the course of doing their jobs. The R&D expenses for such accidental inventions are probably minor.

The existence of patented inventions that were apparently generated at little or no cost serves to remind us that firms do not explicitly pay for some of the most critical inputs in the R&D process. The worker who comes up with an innovative suggestion is surely using the basic skills and knowledge taught in schools and the experience acquired in previous jobs. Indeed, a portion of the worker's wage must be compensation for the valuable knowledge and experience brought to the job. Therefore, we can be reasonably confident that the average education level of the working population—education conceived broadly as years of work experience and formal schooling—also contributes to a nation's TFP growth, although this contribution may be difficult to quantify.

Recognizing that TFP growth may respond to the level of R&D expenditure and the average level of education, economists have begun to examine whether international differences in R&D expenditures and education levels help explain international differences in TFP growth. Since data on productivity are hard to compile, researchers have been content to study whether international differences in R&D expenditures and education levels help explain international differences in per capita GDP growth.

Two authors, Paul Romer (1989) and Frank Lichtenberg (1992), concluded that international differences in per capita GDP growth are influenced by international differences in R&D expenditures. However, a recent study by Nancy Birdsall and Changyong Rhee (1993) found that correcting the data set used by Romer and Lichtenberg for possible measurement errors eliminates this correlation. Therefore, the role of R&D expenditures in the explanation of international differences in TFP growth rates remains an open issue.[5] With regard to education levels, Robert Barro (1991) has documented that countries that start out with low school-enrollment rates grow at a discernably slower rate.

Economies of Scale. A second important determinant of TFP growth is economies of scale. Economies of scale exist if unit costs fall at higher levels of production. Increases in TFP that result from increases in the size or capacity of production facilities represent one type of economies of scale. For instance, in the chemical and petroleum industries the average cost of production is much lower in bigger plants if these plants operate near capacity.[6]

The increase in TFP resulting from economies of scale is distinct from that resulting from a new industrial process. A firm may be aware that a bigger plant, if operated near capacity, lowers costs but may not build or buy a bigger plant if the larger volume of output needed to make it economical cannot be profitably sold. However, with an expansion in market size, bigger plants do become practical and are acquired, thereby contributing to the increase in the productivity of labor and capital.

A second example of economies of scale is the increase in TFP that comes from specialization. Adam Smith in his *Wealth of Nations* noted that the division of labor constitutes a major source of productivity increase. A group of workers in which each worker concentrates on a limited set of tasks produces much more than an equally large group of workers in which each worker performs every task. This gain stems from several factors: less time is lost

[5] R&D expenditures may matter for growth, but differences in R&D spending across countries may not be large enough to appreciably affect productivity growth. Alternatively, a country that invents a new product or process may not be the only one to benefit from it. If inventions are patented and sold to producers in other countries, the purchasing country will also experience an increase in TFP. Indeed, Robert Evenson (1984) documents a brisk international trade in inventions. Therefore, it might be expected that differences in the rate of economic growth due to differences in R&D levels would be difficult to discern in the data.

[6] See Alfred Chandler's book *Scale and Scope: The Dynamics of Industrial Capitalism*, for an in-depth discussion of the role of increasing returns to scale in modern industries.

switching from one task to another; some workers may be better at some tasks than other workers; or simply performing a task many times over entails a gain of efficiency.

The efficiency gain from specialization of tasks within a firm extends to the specialization of production across firms as well: if production is organized so that a large number of firms produce very specialized products (which are then assembled to manufacture the final good), the productivity of labor and capital will be higher. Indeed, a proliferation of intermediate goods used in the production of goods and services always accompanies the industrial development of any country, which suggests that some of the increase in TFP must be due to gains from specialization. Again, a firm may not wish to incur the expenses involved in buying or building more specialized plants if the increased volume of its specialized output cannot be profitably sold in the market.

The economic integration of geographically dispersed markets is perhaps the most significant channel through which economies of scale contribute to the growth of TFP. When regions that did not previously trade with each other begin to do so, market size for producers in both regions expands, making it possible for more and more firms to profitably adopt bigger plants and to profitably specialize.

The integration of markets can come about for various reasons. For instance, the proliferation of railroads contributed to the higher pace of adoption of large-scale production facilities in the U.S. during the 1880s and 1890s. Similarly, the development of the U.S. interstate highway system in the 1950s and 1960s integrated markets even further. More generally, innovations in the transportation sector that reduce the costs of moving goods around have the effect of expanding the geographic size of markets. Removal of trade barriers such as tariffs promotes trade between regions and is another channel through which the geographic size of markets may increase. Edward Denison estimates that the portion of TFP growth that can be accounted for by economies of scale ranges between 23 to 36 percent.

Learning-by-Doing. Economists have identified a third source of TFP growth: learning on the job, or learning-by-doing. As individuals working together in a factory gain experience in the production of a new product or process, they learn to become more efficient, that is, they waste less time and raw materials in producing a given volume of output. Consequently, TFP increases simply as a result of experience. The existence of learning-by-doing is well documented for many manufacturing industries (see the article by Linda Argote and Dennis Epple). As one example, let's consider Alan Searle's 1945 study of the manufacture of Liberty Ships during World War II.

From December 1941 through December 1944, 14 shipyards in the U.S. produced a total of 2458 Liberty Ships, all to the same standardized design. On average, with each doubling of cumulative output, the reduction in manhours required per ship ranged from 12 to 24 percent across the 14 shipyards. Similar reductions in unit manhour requirements were also seen in the production of other ships as well. Leonard Rapping (1965) showed that after accounting for variations in labor hours and capital used in each of the shipyards, the effect of learning was to increase TFP between 11 and 29 percent over the three-year period, i.e., to increase TFP at an annual rate between 4 and 10 percent.

While learning effects can be quite substantial over a two- to three-year period, industry studies also show that TFP growth from learning ultimately stops. For instance, in the case of Liberty Ships, the maximum productivity gain had been achieved by the end of 1943, and productivity was roughly constant over the last year of production. This raises a natural question: can learning-by-doing really be a source of *sustained* increases in TFP? The answer may be yes because, as already noted, new products and new processes get added every year, so that there are fresh opportunities for learning effects to increase TFP.[7]

Indeed, some economists have recently conjectured that the effects of learning-by-doing may be an important part of the explanation of the fast economic growth of countries like Hong Kong, Korea, and Taiwan since the mid-1960s.[8] These countries have not been technological leaders, so their rapid economic growth cannot be ascribed to a rapid pace of invention. Also, although benefits from specialization exist, researchers do not consider them a major factor in the economic growth of these countries. On the other hand, these countries have rapidly added the production of more and more technologically advanced goods to their economy and have certainly been in a position to reap the TFP gains from learning-by-doing. In this they have (somewhat paradoxically) been helped by the fact that they are technological followers: they haven't had to await the outcome of costly R&D efforts to obtain "new" products.

To summarize the discussion so far, economists have identified three important determinants of TFP growth. First, TFP increases because of the invention of new products and processes. Second, it increases because of economies of scale. Third, it increases because individuals in firms learn at their jobs. The degree to which each of these sources contributes to TFP growth depends on the choices that individuals, firms, and governments make: the pace of innovation depends on the amount of resources spent on R&D and education; the importance of economies of scale depends on the speed with which the transportation network of a country develops; the extent to which a country benefits from learning-by-doing depends on how quickly a country expands the production of new goods. Thus, a country's TFP growth is shaped by the choices that its citizens make.

ECONOMIC POLICY AND TFP GROWTH

For an economist, the first and most important issue about economic policy and TFP growth is whether the government should attempt to influence TFP growth at all. Is there reason to believe that individuals and corporations acting in their own interests in this regard do not fulfill the broader interests of society? Is there a serious mismatch between private gain and social benefit in the generation of productivity improvements? This section explores some of the justifications for government intervention with regard to the three sources of TFP growth discussed in the previous section.

Economists recognized early on that the economics of technical progress had some peculiar features to it. Fundamentally, technical progress depends on our understanding of the physical universe; it draws upon the fruits of basic research in the various sciences, including medicine. However, basic research cannot be done for profit because scientists do not have property rights on the laws of nature. Once a scientific discovery is communicated to the scientific community, anyone can use it free of charge. Therefore, the government should, by and large, support basic research. Of course, this raises very thorny issues about the kinds of basic research to fund, whether the level of funding in any year is too little or too much, and exactly how to measure the benefits of past funding on basic research. However, these largely unexplored issues are beyond the scope of this article.

In contrast to basic research, the fruits of applied research are new products that can be sold for profit and new production processes that can lower costs. Therefore, applied re-

[7]The gains from learning-by-doing may be limited for a new product or process if the product or process is not produced to the same specifications each time but is customized to a significant degree.

[8]See, for instance, articles by Robert Lucas (1993), Nancy Stokey (1988), and Alwyn Young (1991).

search can, in principle, fund itself. However, even here there may be a mismatch between private return and social benefits. The mismatch arises because, in many instances, the discovery of a new product or production process stimulates the discovery of other products and processes elsewhere in the economy. If the new discoveries are closely related to the first, patent laws will allow the first discoverer to benefit monetarily from these unexpected and unintended consequences of his discovery provided the original invention was patented. However, more often than not, the discoverer cannot capitalize on these subsequent inventions.

Scholars who have attempted to measure these external benefits of research and development have generally found them to be significant and quite pervasive.[9] Thus, corporations and individuals, guided by the value of inventions to themselves alone, will undertake less R&D than is warranted by the true social benefit of their R&D efforts. Therefore, a case can be made for subsidizing applied commercial research. Again, the issue of subsidies raises difficult questions about which kinds of research should be subsidized, how the benefits from past subsidies should be evaluated, how the incentives for R&D should be structured, and how much subsidy should be provided. The U.S. government subsidizes applied commercial research through government grants and tax breaks, but economists have only an imperfect understanding of these issues.[10]

As noted earlier, the average level of education of the working population is also likely to be an important factor in promoting TFP growth. The government has an obligation to support education for reasons similar to those for supporting R&D. While most individuals value education and are willing to devote time and money to acquire it (or make sure that their family members do), they consider only their private gain. However, education confers innumerable benefits on society as a whole (faster TFP growth is one), so there is a case for subsidizing it. However, as in the case of R&D subsidies, many unresolved issues remain concerning the details of government support for education.[11]

For developing countries, the possibility of achieving TFP growth through economies of scale suggests a special rationale for government intervention. In a nutshell, the rationale stems from the fact that cost-effective large-scale production of one product typically hinges on the cost-effective large-scale production of constituent inputs, and these inputs in turn require large-scale production of other inputs and so on. If a developing country is to replicate this interlocking pattern of large-scale industrial production within a short period of time, it has to advance simultaneously across a broad industrial front. Therefore, an individual firm contemplating investment in a large-scale technology must be reasonably confident that supporting investments in large-scale technologies will occur in other industries.[12] In such a situation, the government can play a vital coordinating role by assisting firms in different sectors of the economy to commit to a common industrial plan. Virtually all developing countries have relied on such coordination of economic activ-

[9]See, for instance, the articles by Adam Jaffe (1986) and Ricardo Caballero and Adam Jaffe (1993).

[10]For an attempt to come to an understanding of this knotty issue, see Linda Cohen and Roger Noll's book *The Technology Pork Barrel*.

[11]For a discussion of the benefits of education, with explicit reference to economic growth and some of the related policy issues, see the article by T. Paul Schultz (1988).

[12]Another option for the firm is to buy the necessary inputs from abroad. However, developing countries often find the domestic price of imported inputs to be prohibitively high so that this option may not be practical.

ity, although its extent and scope have varied greatly.

Other than financing the transportation network, there are no U.S. policies designed to directly affect the advance of TFP through economies of scale. However, some policies inadvertently do so, for example, anti-trust laws and international trade rules. To reap the TFP benefits of economies of scale, firms must enlarge the scope of their operations, which, in many instances, means that a few large firms will have a major share of the market being served.[13] However, economic theory suggests that firms (or groups of firms) that are so big as to have no effective competition from their rivals tend to cut back on the supply of their product so that the artificial scarcity can generate hefty profits for the firm or the group. For this reason, the U.S. legislated anti-trust laws (the Sherman Act of 1890) that prohibit price-fixing agreements and mergers and acquisitions whose main intent is to gouge customers. However, while these laws protect consumers from errant firms, they also slow down the rate of adoption of large-scale technologies because expansions in firm size that typically accompany such adoptions need to be cleared by regulatory authorities. There are no estimates of the adverse impact of anti-trust regulation on TFP growth, but such an impact surely exists.[14] On the other hand, policies to break down barriers to international trade promote larger markets, thus allowing greater economies of scale and TFP growth.

The phenomenon of learning-by-doing *per se* does not suggest a role for government policy. While it is true that uncertainties and setbacks faced during the learning phase might mean that a firm doesn't survive to reap the benefit from learning-by-doing, it does not follow that governments should step in to help out failing firms. If private investors are not willing to risk their money in the venture, why should the government risk the taxpayers' money? Government help is justified only if surviving firms provide benefits (to the economy) for which private investors are not compensated, thereby causing private investment in new ventures to be too low. However, learning-by-doing presumably invests workers and entrepreneurs with skills that are also valuable outside of their existing firm, so that uncompensated benefits from learning-by-doing may well exist. For instance, a worker who breaks away and pioneers a valuable innovation after acquiring useful training in a firm is not obligated to share his newfound wealth with his former employers. If this kind of phenomenon is pervasive, it may be beneficial for governments to subsidize firms during the costly learning-by-doing phase.[15]

CONCLUSIONS

This article makes several important points about economic growth. First, technical progress, which economists call total factor productivity (TFP) growth, has been a major factor underlying increases in output per hour worked in the United States and Europe. In fact, it has been more important than the rising amount of capital available to each worker, although this, too, has contributed.

Second, the constancy of capital-output ratios in the United States and many European

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[13]Indeed, as Chandler's book cited earlier documents, the adoption of large-scale technologies in the last two decades of the nineteenth century went hand in hand with the emergence of monopolies, trusts, and combines.

[14]See Crandall (1980) for a general discussion of government regulations on U.S. productivity growth. Denison (1979) estimates that 13 percent of the decline in productivity growth over the 1965-1978 period was due to increased government regulations.

[15]At least one astute observer of economic life believes that innovators are frequently breakaways. See Jane Jacobs' *The Economy of Cities.*

countries suggests that accumulation of capital stock in these countries has been mostly in response to their TFP growth. Thus, it is reasonable to think that *differences* in growth of output per hour worked across these countries are mostly the result of *differences* in TFP growth.

Third, the TFP growth experienced by a country is a result of the pace of innovations and inventions, the extent of the economies of scale experienced by the country, and the extent of productivity improvements from learning-by-doing. These sources of TFP growth in turn depend on profit calculations of individuals and firms and the wisdom of government policies. Therefore, there is a potential economic explanation for the differences in TFP growth across countries and for the same country over time. However, despite these advances in our understanding of economic growth, there's a great deal still to be learned, especially in the area of designing economic policies to promote productivity growth.

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