# THE "NEW ECONOMY", SOLOW'S PARADOX, AND ECONOMIC HISTORY

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## ABSTRACT

Criticism of economists' failure to find evidence of increased productivity from the use of new technology stems from a misunderstanding of basic economic theory, carelessness with the empirical evidence, and lack of historical perspective. Despite recent calls for a "new paradigm", three basic macroeconomic tools show that the old rules and principles still apply. There have been other periods of economic history that have caused more structural economic change than the recent "technology revolution".

## Introduction

In recent popular discussion, there are increasing references to the "new economy". The phrase has made its way into newspapers, magazines, business publications, and government documents, and is often heard in conferences, classrooms and speeches. The phrase has graced the covers of major popular printed media,[1] has been the topic of a special report of a major cable television network, and a speech of the Chairman of the Federal Reserve.[2] It has even been given the blessing of the U.S. President ("I do believe in the new economy").[3]

The "new economy" is a story about technology, especially information technology. Technological advances, so the story goes, have caused a structural change in our economy leading to ever-higher productivity growth, to the point that we now require a new paradigm. Among the new economy proponents, *Business Week* claims that computers and telecommunications are "undermining the old order" and leading to a "radical restructuring" of our economy. This is no ordinary change, for "information technology ... is, in short, a transcendent technology — like railroads in the 19th century and automobiles in the 20th century."[4] Not to be outdone in exuberance, *Wired* magazine executive editor Kevin Kelly writes that the new economy is producing a "tectonic upheaval" that is "tearing the old laws of wealth apart."[5] And we can expect the trend to continue, since the "new economy — so far propelled mainly by information technology — may turn out to be only the initial stage of a much broader flowering of technological, business, and financial creativity."[6]

This popular story ignores one very important fact: there has been little increase in measured productivity in the U.S. economy since the mid-1970s. This phenomenon has been labeled the productivity paradox, or "Solow's paradox", stemming from his remark in 1987 that "you can see the computer age everywhere but in the productivity statistics."[7] Though recent revisions of the national income accounts have made the

productivity slowdown seem less severe than was previously thought, economists can find little empirical evidence of a new economy.

Such a denial is unacceptable to the new economy adherents. *Business Week* claims that traditional analysts of the new economy are "unable to explain what is going on" because they are "wedded to deeply flawed statistics and models."[8] Kelly, of course, resorts to a more imaginative rhetoric: "It's possible the gauges are all broken, but it's much more likely that the world is turning upside down."[9] Some even see the denial of the new economy as "propaganda being spread by Alan Greenspan and his cohorts."[10]

There is no definitive statement about precisely what is meant by the "new economy."[11] It is difficult to sort through the technological adoration and cheerleading, but criticisms of economics by the technologists seem to indicate that the following three points would make up at least part of the platform.

1. The tremendous investment in computer equipment (at a rate of over 20% per year in the past decade) has led to new products, new methods of production (new "capabilities"), and new technological feats. Diffusion into products outside the original designation of the new technology has led to considerable "spillover" effects. This has fundamentally changed the structure of our economy, increasing the productivity of our workforce, which in turn is giving us a potential for unprecedented prosperity. Because of the change in basic structure, it is difficult to measure the changes in productivity, but there is no doubt that our economy is capable of greater economic growth.[12]

2. The unprecedented length of the current expansion (as of January, 2000), with unemployment rates at 30-year lows and negligible inflation rates, indicates that the tradeoff between inflation and unemployment has broken down. In a related argument, the rate of unemployment at which inflation begins to accelerate (the "natural rate" of unemployment, or the "non-accelerating inflation rate of unemployment" — the NAIRU) is now lower than it was a decade ago. This argument is often manifested in criticism of Federal Reserve actions that increase interest rates with increases in economic growth.

3. The growth of "networks" (a result of how technology has changed the way we communicate) has changed basic production foundations. One firm's investment in technology (say, in a fax machine or internet connection) has very little value by itself. Its value depends on the investment by consumers and other firms in the new "network economy." If you "connect a hundred of them together, they're worth something; connect 10,000, they're worth a lot."[13] In fact, it's "the reverse of the law of diminishing returns" with the result that "scarcity is no longer a definer of value."[14] The implication is that society will find greater economic growth without the tradeoffs that were necessary in the "old economy."

The popular discussion needs a more somber tone. I contend that much of the criticism of economists' failure to find evidence of a new economy stems from a misunderstanding of basic macroeconomics. I do not deny that there have been tremendous technological advances in our recent experience. But a technological revolution is not an economic revolution. If traditional macroeconomic models can best explain the

observed data, then there is no need for a new paradigm. To that end, I attempt to survey three basic macroeconomic tools (as opposed to "schools")— the Solow growth model, Okun's Law, and the Phillips curve — and show that the old rules and principles still apply, though with possibly different parameters. I also argue that although the new economy proponents are correct in arguing that much of the productivity puzzle can be explained by mismeasurement of the productivity data, a careful analysis of the data is more appropriate than reliance on anecdote.

## Solow's growth model

The basic foundation of the traditional macroeconomics approach to understanding economic growth is the *production function*. Essentially, the production function expresses the relationship between the economy's output (gross domestic product), and the resources that are used to produce the output. Resources, sometimes referred to as "factors of production" are divided into two categories.

1. capital: something that is produced not for consumption, but in order to produce other goods that are intended for consumption; this includes tools, machinery, equipment, plant, and so on.

2. labor: human resources used in productive activity; this includes not only the number of workers employed in the labor force and the time they spend in productive activity, but the skills, knowledge, energy, etc., that are possessed by people. These characteristics that people carry with them to the labor force are often called "human capital."

Production of output requires the use of both capital and labor, but these resources can be used in many different combinations. The way in which output depends on these resources is implied by the available technology. The production function is often expressed mathematically as

$$Y = F(K,L)$$

where Y is the economy's output, K is the stock of physical capital, and L is labor. The symbol F represents the particular form of the function, which captures in a general way the available technology.

Economists try to simplify the way we look at production by holding some things constant while varying others. One could consider it a list of the possible ways in which output, resources, and technology are related.

1. **If capital and technology are held constant:** Increases in labor increase output. However, as labor increases, the increases in output get smaller. This is what economists call "diminishing returns." Because of diminishing returns, increases in labor will likely result in lower labor productivity (measured as output per unit of labor).

2. **If labor and technology are held constant:** Increases in capital increase output. This increase in capital is also subject to diminishing returns. But notice that an increase in capital will also raise labor productivity.

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3. **If output and technology are held constant:** An increase in capital (which increases output) is accompanied by a decrease in labor (which reduces output), so that the changes in output cancel each other out. Economists refer to this as "input substitution." Note that in this scenario, capital has replaced labor. But also note that labor productivity is increased since labor resources have been reduced (diminishing returns in reverse).

4. **If capital and labor are held constant:** Improvements in technology increase output. In this case, something happens that changes the way in which resources are used to produce the output. This is represented by a change in the value of F in the mathematical expression of the production function. Note that improvements in technology raise not only labor productivity, but the productivity of capital as well.

In the first three listed scenarios, there is no change in technology. Yet there are changes in the productivity of the resources. These changes in productivity are caused by a change in the *mix* of resources used to produce the output. And where the productivity of one resource increases, the productivity of the other declines.

It is only the last scenario that specifies a change in technology. Notice there that the levels of capital and labor remain unchanged, yet output increases. This means that the productivity of *both* labor and capital has increased. Economists refer to this phenomenon as *multi-factor productivity*, and is what Solow meant when he referred to the "productivity statistics."[15] And apparently this is the source of most of the confusion in the popular discussion.

Of course, in the real world there can be simultaneous changes in labor, capital, and technology. But at least with this model we can sort through the effects of the changes. What is needed next is a way to measure these variables, and a look at the actual data. We might then be able to tell which of the three scenarios best explains recent economic experience (or at least which one predominates).

Solow's contribution to the analysis of how technological change can affect economic growth is not merely the development of a model.[16] He also provided a unique method of measuring it.[17] Notice from the model that any growth in output (commonly labeled "economic growth") must be due to growth in three things: growth of the capital stock, growth of the labor force, and technological change (or growth in multi-factor productivity). We have data on growth in output, capital, and labor. Technological change is, of course, unobservable and thus unmeasurable. But the growth in total factor productivity can be computed indirectly as a residual — that is, as the amount of output growth that remains after accounting for the determinants of growth that we can measure. In fact, multi-factor productivity is often referred to by economists as the "Solow residual."

Table 1 decomposes the economic growth of the United States from 1950-1999. As the table shows, economic growth of the 1990s was unremarkable when compared to the average growth of the last half of the 20th century. Total factor productivity in the age of the computer (the 1980s and 1990s) was higher than the 1970s, but overall was less than the 1950s and 1960s. It would appear, at least from an examination of the productivity statistics, that there is no evidence of a "new economy."

| Table 1: Sources of Growth in the U.S. (average annual percentage increase) | | | |
|---|---|---|---|
| Time period | Output growth | Contribution of capital | Contribution of labor | Total factor productivity |
| 1950–1960 | 3.5 | 1.1 | 0.8 | 1.6 |
| 1960–1970 | 4.1 | 1.2 | 1.3 | 1.7 |
| 1970–1980 | 3.1 | 0.9 | 1.6 | 0.5 |
| 1980–1990 | 2.9 | 0.8 | 1.3 | 0.8 |
| 1990–1999 | 3.2 | 0.8 | 0.9 | 1.5 |
| average | 3.4 | 1.0 | 1.2 | 1.2 |
| source: U.S. Department of Commerce, U.S. Department of Labor, and author's calculations | | | |

The productivity statistics provided in the table must, however, be more carefully considered. Because total factor productivity is a residual, there may be factors other than technological progress that causes it to change. And the calculations assume, of course, that the other variables are correctly measured. For example, increased public expenditures on health and education might improve the human capital that workers bring with them to the labor force. While the model would include this as an increase in labor, the data may not. And the decomposition of economic growth would include this in the Solow residual. It is important to remember that anything that changes the relationship between measured inputs and measured output is attributed to total factor productivity.

There may be, therefore, a mismeasurement story to the productivity puzzle. This is easily seen if one takes computers themselves as an example. If technological advance leads to *more* computers being built, then we could easily calculate the increase in output and productivity. But if the technological advance leads to *faster* computers being built, output and productivity would have increased, but would be much more difficult to measure. Other unmeasured quality improvements would lead to an underestimate of our economic growth.

To further complicate the issue, the Commerce Department in 1999 revised the GDP accounts to include better information and statistical techniques, and to reclassify computer software as an investment rather than a business expense. The result is that output growth has been revised upward, though there is still an apparent slowdown in economic growth since the 1970s, and there has been no structural improvement in productivity outside of durable manufacturing and the computer industry itself.[18] But to use mismeasurement to explain a *slowdown* in the rate of economic growth, the mismeasurement must have gotten *worse* over time. And there is some evidence that this is the case, since our economic output is increasingly comprised of things that are difficult to measure (for example, fewer manufacturing products and more services).[19] But few economists believe that measurement problems are the full story. Sichel estimates that only about 0.23 percent of the productivity slowdown between 1973 and 1990 can be attributed to this phenomenon.[20] In a different approach, Carlson and Schweitzer estimate the upper bound on the potential contribu-

tion of a mismeasurement gap (that is, under conditions that are *most* favorable to the mismeasurement story) to add no more than a half percent to productivity growth, leading them to the conclusion "that the mismeasurement hypothesis is a weak reed to lean on" for new economy advocates.[21]

Is there another solution to the paradox? Can one of the other three scenarios (other than a change in technology) listed above provide an explanation for what we observe in the data? Or do we need a "new paradigm?"

It turns out that the explanation is rather simple. First, note that in the specification of the production function, there is no reason that we cannot separate capital into various categories rather than lump it all into one. For the present discussion, we could separate capital into "computer capital" (label it Kc) and "noncomputer capital" (and label it Kn). Then the production function would be specified as Y=F(Kc,Kn,L). There are no changes in the properties of the production function, since K=Kc+Kn. The difference is that the new specification might allow us to observe something that the original could not: there may be substitution of computers for other forms of capital. In a very straightforward presentation of the evidence, Jorgenson and Stiroh show this to be the case.[22] The reason for the increased use of computers and their substitution for other inputs is also rather obvious: computer prices have fallen.

So, the best explanation of "Solow's paradox" seems to be the third in the list of scenarios. The story is one of input substitution, not technological change. The relatively swift declines in computer prices have led to huge investments in information technology equipment, and this equipment has been substituted for other inputs. The changes in output from this substitution have nearly cancelled out, resulting in very little economic growth.

## Okun's Law

The Solow growth model is best used to explain changes in real GDP over a long-run period of time (which is why the calculations in Table 1 are by decade). That is to say, Solow's model describes the long-run trend growth — the "normal" growth — in real GDP. The "new economy" may have changed fundamental short-run economic relationships so that deviations around the trend are different from past experience. One such possibility is the relationship between economic growth and unemployment rates.

When the economy's output is increasing faster than normal (above trend), unemployment rates tend to decrease. Likewise, lower-than-normal growth in real GDP tends to be associated with increases in unemployment rates. This negative association between the percentage change in real GDP and unemployment rates has been so remarkably stable over the past several decades that the relationship has been given the name "Okun's Law."[23]

Using data from 1960 to 1998 (and this is the revised data mentioned in a previous section), an ordinary least squares regression yields the following results:

$$y = 3.38 - 193u,$$
$$R^2 = .7434,$$

where $y$ is the percentage change in real GDP and $u$ is the change in the unemployment rate. The t-statistics for the intercept and slope are 19.41 and -10.35 respectively, which are both significant at the 0.0001 level.

This says that for every percentage point the unemployment rate rose, real GDP growth fell, on average for the 39-year period, by 1.93 percent (which is very consistent with the rule-of-thumb 2 percent cited in macroeconomic textbooks). The growth rate at which unemployment was neither increasing nor decreasing was 3.38 percent; this is the "normal" or trend growth rate which is due to increases in labor, capital accumulation, and technological progress. Whenever the economy grew above the trend growth rate of 3.38 percent, unemployment rates rose; whenever the economy fell below this trend growth rate, unemployment rates increased. A scatterplot of the data, with the regression line superimposed, is presented in Figure 1 below.

**Figure 1. Okun's Law**
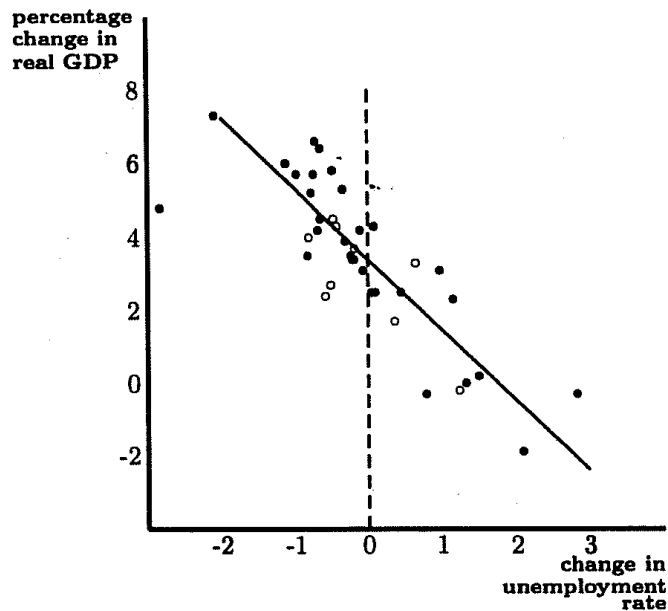


The black-filled points in Figure 1 represent the years 1960-1989; the hollow points the years 1990-1998. As the figure reveals, the 1990s were unremarkable when compared with observations from the entire time period. Only three of the most recent nine observations lie above the regression line, the remainder lie below it (one appears to lie *on* the line, but is actually slightly below it). It would seem that Okun's Law has withstood any attempt at repeal by the "new economy."

## Phillip's Curve

While Okun's Law shows that decreases in unemployment rates can increase real GDP in the short-run, it says nothing about wages and prices. Most economists would contend that increases in real GDP above trend, brought about by reductions in unemployment rates, will not last long without increasing wages and prices. The converse is true, of course, for increases in unemployment rates and falls in real GDP. The relationship between unemployment rates and wage changes (or sometimes price level changes) is known as the "Phillip's Curve."[24] Modern versions of the Phillips curve are derived from models of aggregate supply, and contain three components: expected inflation, cyclical unemployment, and supply shocks.

The interaction of the demand for and supply of labor determines the *real* wage rate. If inflation is zero, or nearly so, then nominal wages reflect labor productivity. In the presence of inflation, workers desire to maintain their real income, and so build into nominal wage demands any expectation of inflation. This means that any model of the Phillips curve must contain some specification of how expectations are formed. Since this essay is not intended to present a discussion of esoteric models, I will make the assumption that expectations are on average correct, so that the expected rate of inflation equals the actual rate. This assumption is probably quite accurate for the 1990s, as inflation rates were quite low and slowly declining.

In search theory, the rate at which unemployed individuals find jobs and the rate of job separation for employed individuals determine a steady-state or equilibrium rate of unemployment. The economy tends to gravitate toward this particular rate, and is called the "natural rate of unemployment." It is, of course, related to Okun's Law. The deviation of output from its trend is inversely related to the deviation of unemployment from its natural rate. If unemployment is below its natural rate (output is above its trend), we can expect wages (and prices) to increase over time, and the unemployment rate will tend back toward its natural rate. If unemployment is above its natural rate (output is below its trend), then wages (and prices) will decline over time.

In the absence of supply shocks, changes in wages not due to productivity are the sum of expected inflation and the deviation of unemployment from its natural rate (the cyclical component). If expected inflation is equal to actual inflation, then we should observe a negative relationship between unemployment rates and the *real* wage. An OLS regression of unemployment rates on real wages from 1990-1998 yields the following results:
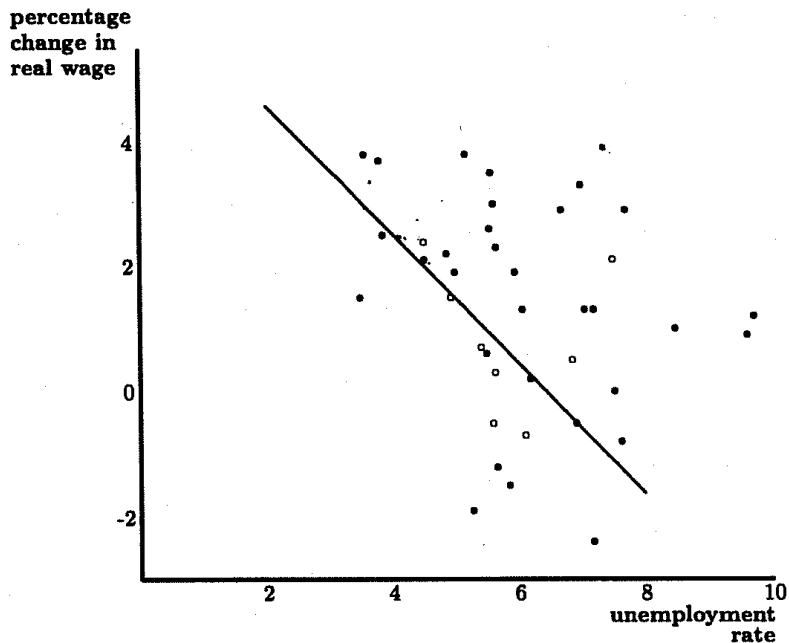
$$w = 6.667 - 1.0369 \ U,$$
$$R^2 = .7064,$$

where $w$ is the percentage change in the real wage, and $U$ is the unemployment rate. The t-statistics for the intercept and slope are 4.818 and -4.499 respectively, which are both significant at the 0.01 level. The data are plotted in Figure 2 below.

**Figure 2. Phillip's Curve**



The hollow points are, again, the 1990-1998 period, while the black-filled points are for 1960-1989. The regression line for the 1990-1998 period is superimposed. If anything, the relationship between real wages and unemployment rates is *stronger* for the 1990s than for any other period (this is for a particular model of expectations formation — that the expected rate of inflation is equal to the actual rate. In other time periods, other expectations models may be more appropriate).

Economics professors are fond of using the 1970s to show how the increase in oil prices resulted in a "supply shock" that caused the Phillips curve to shift. The short-run negative relationship was still there, but the curve shifted outward from the origin of Figure 2. It could be that the emphasis on the 1970s period has taken attention away from the possibility of "positive" supply shocks that cause the Phillip's curve to shift toward the origin. This may explain the erroneous conclusion that the Phillip's relationship has broken down. Much of the 1990s experience, such as declining oil prices, resulted in an inward shift of the Phillips curve. This is evidenced by the data points lying above the 1990s regression line of Figure 2.

It is becoming increasingly obvious that the labor market in the United States is becoming less inflation-prone, and some have concluded that the idea of a natural rate of unemployment should be abandoned.[25] But the natural rate of unemployment is not immutable, which Friedman pointed out in his introduction of the concept.[26] It is possible that the natural rate of unemployment has fallen, meaning that the U.S. economy can today sustain lower rates of unemployment, without accompanying inflation, than in the past.

In calculating unemployment rates, the population is divided into three categories: employed, unemployed, and not in the labor force. The natural rate of unemployment is determined by the rate at which people find jobs (move from the state of "unemployed" to employed"), the rate of which workers lose jobs (move from "employed" to "unemployed"), and any change in labor force participation rate (movement to and from "out of the labor force" to either "employed" or "unemployed"). A change in any of these transition rates will change the natural rate of unemployment. It is even possible that technological changes have been the cause of the decline in the natural rate.

Katz and Krueger have studied recent changes is the U.S. labor market to conclude that the natural rate of unemployment is, indeed, lower than it has been in the past 25 years or so.[27] They attribute the decrease to three primary factors: (1) the increasing median age of the working population (the aging baby boomers – and older workers have lower unemployment rates), (2) the growth in the temporary help industry (which increased the job finding rate), and (3) a rising prison population (prisoners are not included in the unemployment statistics, and this is a population that typically has higher unemployment rates when not incarcerated). The beneficial change has apparently not been due to technology, but to demographic shifts and labor market intermediaries.

## Technological History

Some recent work in economics has broadened the historical perspective to include a time frame long enough to include transitions from one technological regime to another. And perhaps a different picture emerges.

From a millenial perspective, increases in standards of living are relatively recent in the history of mankind. For thousands of years, economies of the world experienced negligable, if any, economic growth. Only since the nineteenth century has there been any substantial increase in living standards. Fogel attributes this to rapid *acceleration* in technological change.[28] By charting major events in the technological history of mankind, Fogel makes it obvious that most of the meaningful technological changes experienced by mankind have occurred only in the last 200 years. He also points out that prior to 1600, centuries elapsed between major technological advances, and the diffusion of those advances continued over several millennia.

In a centurial view, economic historians such as David and Greenwood are showing us that important technological changes in the past, such as spinning technologies and steam engines in the 1760s, and electicity and the automobile in the late 1800s, had long adoptive periods.[29] The introduction of these technologies initially led to lower productivity and wages as firms and workers learned how to exploit the new innovations. After the new technologies diffused throughout society, productivity and wages increased at a higher rate. The same may be true of computers. The productivity slowdown in the 1970s that persisted through the 1980s and the early 1990s may be

due to society adopting the new information technology. If so, the recent increase in productivity may be the beginning of a long-run trend that will eventually lead to higher wages and living standards. We may be seeing a "new economy" after all. One must be careful, however, in adopting this conclusion. Recent technological changes may not have the same impact in the twenty-first century as they did in the eighteenth and nineteenth. As Fogel points out, and as Triplett reminds us, for technology to improve our productivity, the *rate* of technological progress must be higher than in the past.[30] As an economy grows, an ever larger number of new technologies is required just to keep the productivity growth rate constant. If we look at the new products and new technologies that have been thrust upon us at the turn of the century, we are truly amazed. But if one reads the popular literature of, say, the early 1960s, the same amazement existed then as well. The question is not whether we see increases in technology. The question is: are they increasing at an increasing rate?

Even if the rate of technological advance continues to increase at ever higher rates, do we need a new paradigm to go along with the "new economy?" I think not, at least not yet. When the new information technology is held up to Fogel's list of the major technical events of history, one must wonder whether computers are really as important as the invention of the plow, or railroads, or the automobile. Has the internet already changed our economy to a greater extent than telephony did at the turn of the century? How about televison? What I am saying is that history is replete with "revolutions" that restructure industries, create fortunes, improve our economic well-being, and even change societal structure. But in the end, we are left with an economy that works pretty much in the same way.

## Conclusion

There is currently no evidence that recent technological changes have fundamentally changed our economy. At least, not to the extent that our old economic models no longer serve us. But if those technological changes are going through a long-run phase of adoption, we may see accumulating evidence in the future of a fundamental structural change. It is simply too early to tell. So we must wait.

The engineers, technologists, and economists have exhausted their arguments. But that does not mean that the analysis must end. If technological changes have not improved our productive performance, they *have* changed our lives. What we now need is a study of technology itself — not of how to use it or appropriate it for our needs, but of the consequences of its adoption on how we live. The more important stories may now be those told in anthropology, history, and the even the humanities.

## Notes

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2. Alan Greenspan, "Question: Is There a New Economy?" *Remarks at the Haas Annual Business Faculty Research Dialogue*, September 1998.

3. The quote is attributed to President Clinton in Richard S. Dunham, "I Do Believe in the New Economy," *Business Week* (July 12, 1999).

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7. Robert M. Solow, "We'd Better Watch Out," *New York Times Book Review* (July 27, 1987):36.

8. Shepard, "New Economy," 39.

9. Kelly, *New Rules*, 3.

10. William A. Sahlman, "The New Economy is Stronger Than You Think," *Harvard Business Review* 77, no. 6 (November-December 1999):99-108.

11. Kevin J. Stiroh, "Is There a New Economy?" *Challenge* 42, no. 4 (July-August, 1999):82-93.

12. Shepard, "New Economy," 40.

13. Tim Ferguson, "Paradigm Change (Theories of a New Economy)," *Forbes* (March 8, 1999):90.

14. Ibid., 90.

15. Solow, "We'd Better," 36.

16. Robert M. Solow, "A Contribution to the Theory of Economic Growth," *Quarterly Journal of Economics* 70, (February 1956):65-94.

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23. Named for work done by Arthur M. Okun, "Potential GNP: Its Measurement and Significance," in *Proceedings of the Business and Economics Statistics Section* (Washington, D.C.: American Statistical Association, 1963).

24. Named for work done by A. W. Phillips, "The Relation Between Unemployment and the Rate of Change in Money Wages in the United Kingdom, 1861-1957," *Economica* 25, (November, 1957):283-299.

25. Mandel, "21ˢᵗ Century", 60.

26. Milton Friedman, "The Role of Monetary Policy," *American Economic Review* 58, no. 1 (March, 1968):1-17.

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