

For release on delivery
7:30 p.m. EDT
October 28, 1999

Remarks by
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Chairman
Board of Governors of the Federal Reserve System
before
The Business Council
Boca Raton, Florida
October 28, 1999

Your focus on technology—particularly the Internet—and its implications is most timely, because as this century draws to a close, the defining characteristic of the wave of technological innovation sweeping over the U.S. economy is the role of information.

The veritable avalanche of real-time data has facilitated a marked reduction in the hours of work required per unit of output and a broad expansion of newer products whose output has absorbed the workforce no longer needed to sustain the previous level and composition of production. The result during the last five years has been a major acceleration in productivity and, as a consequence, a marked increase in standards of living for the average American household.

Prior to this revolution in technology, most twentieth-century business decisionmaking had been hampered by less abundant information. Owing to the paucity of timely knowledge of customers' needs and of the location of inventories and materials flows throughout complex production systems, businesses, as many of you well remember, required substantial programmed redundancies to function effectively.

Doubling up on materials and people was essential as backup to the inevitable misjudgments of the real-time state of play in a company. Decisions were made from information that was hours, days, or even weeks old. Accordingly, production planning required costly inventory safety stocks and backup teams of people to respond to the unanticipated and the misjudged.

Large remnants of information void, of course, still persist, and forecasts of future events on which all business decisions ultimately depend are still unavoidably uncertain. But the remarkable surge in the availability of timely information in recent years has enabled business management to remove large swaths of inventory safety stocks and worker redundancies.

Businesses not only respond more accurately to changes in demand, they can respond more quickly and efficiently as well. Information access in real time—resulting, for example, from such processes as electronic data interface between the retail checkout counter and the factory floor, or the satellite location of trucks—has fostered marked reductions in delivery lead times and the related workhours required for the production of all sorts of goods, from books to capital equipment. This, in turn, has reduced the relative size of the overall capital structure necessary to turn out our goods and services.

Intermediate production and distribution processes, so essential when information and quality control were poor, are being reduced in scale and, in some cases, eliminated. The increasing ubiquitousness of Internet sites is promising to significantly alter the way large parts of our distribution system are managed.

The process of innovation goes beyond the factory floor or distribution channels. Design times have fallen dramatically as computer modeling has eliminated the need, for example, of the large staff of architectural specification—drafters previously required for building projects. Medical diagnoses are more thorough, accurate, and far faster, with access to heretofore unavailable information. Treatment is accordingly hastened, and hours of procedures eliminated. In addition, the dramatic advances in biotechnology are significantly increasing a broad range of productivity—expanding efforts in areas from agriculture to medicine.

One result of the more-rapid pace of innovation has been an evident acceleration of the process of "creative destruction," which has been reflected in the shifting of capital from failing technologies into those technologies at the cutting edge. The process of capital reallocation across the economy has been assisted by a significant unbundling of risks in capital markets made possible by the development of innovative financial products.

Every innovation has suggested further possibilities to profitably meet increasingly sophisticated consumer demands. A significant percentage of new ventures fail. But among those that genuinely reduce costs or enhance consumer choice, many will prosper.

The newer technologies, as I indicated earlier, have facilitated a dramatic foreshortening of the lead times on the delivery of capital equipment over the past decade. When lead times for equipment are long, the equipment must have multiple capabilities to deal with the plausible range of business needs likely to occur after these capital goods are delivered and installed. In essence, those capital investments must be structured in a manner sufficient to provide insurance against uncertain future demands. As lead times have declined, a consequence of newer technologies, less judgment about the potential alternative economic environments in which the newly ordered equipment will be functioning is needed. Accordingly, foreshortened future requirements have become somewhat less clouded, and the desired amount of lead-time insurance, in the form of what after the fact would turn out to have been a partially unproductive addition to the capital stock, has declined.

Indeed, these processes emphasize the essence of information technology—the expansion of knowledge, and its obverse, the reduction in uncertainty. The use of information in business decisionmaking can be best described as an effort to reduce the fog surrounding the future outcomes of current decisions.

Because the future is never entirely predictable, risk in any business action committed to the future—that is, virtually all business actions—can be reduced but never eliminated. Information technologies have improved our real-time understanding of production processes, reducing the degree of uncertainty and, hence, risk. This, in turn, has lessened the need for a whole series of programmed redundancies from which, in the end, little to no productive capability is achieved.

In short, information technology raises output per hour in the total economy by reducing hours worked on activities needed to guard productive processes against the unknown and the unanticipated. Narrowing the uncertainties reduces the number of hours required to maintain any given level of readiness.

But, obviously, not all technologies, information or otherwise, affect productivity by reducing the inputs necessary to produce the current level of existing products. Some information made possible by technological advance more readily contributes to developing new products that consumers value rather than to reducing the required inputs for existing products. Indeed, in our dynamic labor markets, the resources made redundant by better information are drawn to newer activities and newer products, many never before contemplated or available.

The personal computer, with its ever-widening applications in homes and businesses, is one. So are the fax and the ubiquitous cell phone. The newer biotech innovations are most especially of this type, particularly the remarkable breadth of medical and pharmacological product development. Information has armed many firms with detailed data to fashion product specifications to most individual customer needs. Owing to advancing information capabilities and the resulting emergence of more accurate price signals and less costly price discovery, many market participants are better able to detect and to respond to finely calibrated nuances in customer demand. Value added, accordingly, is enhanced per workhour.

The Internet offers an admixture of potential new goods and services and potential lower costs of production. A major part of our current GDP reflects distribution cost, and it is evident that much of that is subject to potential competitive reduction through Internet marketing. I do not perceive the end of the shopping mall, if for no other reason than I have been strongly advised that shopping is not solely an economic phenomenon. But the relationship between businesses and consumers already is being changed by the expanding opportunities for e-

commerce. The forces unleashed by the Internet may be even more potent within and among businesses, where uncertainties are being reduced by improving the quantity, the reliability, and the timeliness of information, as I am sure your sessions today and tomorrow will have made clear.

The newer technologies obviously can increase outputs or reduce inputs only if they are embodied in capital investment. Capital investment here is defined in the broadest sense as any outlay that enhances capital asset values or, for that matter, even enhances the value of an idea.

But for capital investments to be made, the prospective rate of return on their implementation must exceed the cost of capital. That has clearly happened in the last five years.

In particular, technological synergies appear to be currently engendering an ever-widening array of prospective new capital investments that offer profitable cost displacement. In a consolidated sense, reduced cost is reflected mainly in reduced labor cost or, in productivity terms, fewer hours worked per unit of output.

It would be an exaggeration to imply that whenever a cost increase emerges on the horizon, there is a capital investment that is available to quell it. Yet the veritable explosion of equipment and software spending that has raised the growth of the capital stock dramatically over the past five years could hardly have occurred without a large increase in the pool of profitable projects becoming available to business planners. Had high prospective returns on these projects not materialized, the current capital equipment investment boom—there is no better word—would have petered out long ago. Indeed, equipment and capitalized software outlays as a percentage of GDP in current dollars are at their highest level in post-World War II history.

To be sure, there is also a virtuous cycle at play here. A whole new set of profitable investments raises productivity, which for a time raises profits—spurring further investment and

consumption. At the same time, faster productivity growth keeps a lid on unit costs and prices. Firms hesitate to raise prices for fear that their competitors will be able, with lower costs from new investments, to wrest market share from them. Such circumstances lead to a very favorable period of strong growth of real output and low inflation.

But the degree to which the growth rate of productivity has been rising—indeed, whether in a long-term sense it is rising at all—is subject to considerable debate among economists. This results, in part, from major disputes about our national data system.

Gross product per workhour measured for the nonfarm business sector, employing the newly revised data made available this morning, rose an average 2-1/4 percent per year over the past five years, and nearly 2-3/4 percent over the past two, after averaging 1-3/4 percent over the previous two decades. Because in the past we have had episodes of similar improvements in productivity performance that failed to persist, these data, on their own, cannot be relied upon to draw broad conclusions about whether an acceleration in trend productivity is under way.

But other data are more compelling. Growth in gross domestic income has outstripped the growth of the conceptually equivalent gross domestic product in recent years, producing a dramatic widening of the statistical discrepancy. Productivity growth in the nonfarm business sector, estimated as real gross income per hour rather than real gross product per hour, over the past two years is, thus, a more noticeable 3-3/4 percent at an annual rate, 1 percentage point faster than measured from the product side.

Finally, because the measured level of productivity in the noncorporate business sector exhibits noncredible weakness for substantial spans of time, I believe data for the nonfinancial corporate sector afford a more accurate, though admittedly more narrow, measure of productivity performance. And here the numbers are still more impressive, nearly 3 percent on average over the past five years, and more than 4 percent over the past two. By this measure,

productivity growth in the 1970s and 1980s also averaged about 1–3/4 percent per year.

Moreover, the acceleration in productivity appears reasonably widespread among nonfinancial corporate firms beyond the high–tech industries themselves, even though gains in output per hour in the advanced technology companies have verged on the awesome.

Although it still is possible to argue that the evident increase in productivity growth is ephemeral, I find such arguments hard to believe, and I suspect that most in this audience would agree.

But how long can we expect this remarkable period of innovation to continue? Many, if not most, of you will argue it is still in its early stages. Lou Gerstner (IBM) testified before Congress a few months ago that we are only five years into a thirty–year cycle of technological change. I have no reason to dispute that, although forecasting the evolution of technology is a particularly precarious activity. It nonetheless seems likely that we will continue to experience vast advances in the application of the newer technologies and their associated increases in output per workhour.

But in gauging pressures on cost growth and prices, the critical issue is not how much of the current wave of innovation lies ahead of us, but how rapidly the exploitation of the newer technological synergies proceeds.

If, using Gerstner’s figure, the remaining twenty–five years of the thirty–year cycle of technological change is exploited at a much more leisurely pace than the first five years, the rate of productivity growth will fall. To be sure, the level of productivity will continue to rise but at a slower pace.

A leveling out or decline in the growth of productivity would have a profound effect on the intermediate outlook should it occur. I say, should it occur, because evidence of a downward bend point in productivity growth is not yet evident in our most recent data. All the same, the

rate of growth of productivity cannot continue to increase indefinitely. At some point it must, at least, plateau. Should, at that point, labor market tightness result in faster growth of nominal wage rates, there would be no offset from accelerating productivity. As a consequence, unit costs would likely rise, pressuring profit margins and prices.

That scenario of rising cost and price pressure is one policymakers have dealt with before, and the actions called for, while by no means easy, are readily discernible. What modern monetary policymaking has not faced for quite some time, if ever, has been a major surge in innovation—matching, if not exceeding, the other great waves this century—followed by an apparent elevation of productivity growth. Yet even these welcomed circumstances create challenges for policymakers.

Accelerating productivity poses a significant complication for economic forecasting. For many years, forecasters could assume a modest, but stable, trend productivity growth rate and fairly predictable growth in the labor force. Given the resulting growth of potential GDP, forecasting largely involved evaluating demand growth. If it appeared to be running in excess of trends in potential, the economy could be expected to eventually overheat, with inflation and interest rates moving up. In the end, the economy would, at some point, fall into recession.

With trend growth in productivity now clearly in play, the weakness of a simple demand-side evaluation of economic forces has been brought into sharp focus. It may no longer be the case that an acceleration in demand presages an overheated and unstable economy, if the demand growth is caused by growth in trend productivity. Higher productivity growth must eventually show up as increases in employee real incomes, in profit, or more generally both. Unless the propensity to spend out of real incomes falls, consumption and investment growth will rise, as indeed they must over time if demand is to keep pace with faster supply.

But consumer demand can accelerate so much that total demand could rise above even the productivity-augmented overall growth of potential. This seems to have been happening in recent years, owing to an expanding net worth of households relative to income and perhaps a perception that the recent acceleration in real incomes will continue.

This extra demand can be met only with increased imports or with new domestic output produced by employing additional workers either from drawing down the pool of those seeking work, or from increasing net immigration.

Imports presumably can continue to expand for awhile, since the rising rate of return on U.S. assets has attracted private capital inflows, particularly a major acceleration of direct foreign investment, into the United States. For the recent past, direct foreign investment inflows have almost matched the total current account deficit. But a continued widening of that deficit could eventually raise financing difficulties, ultimately limiting import growth.

In addition, over the past two years, the pool of people seeking jobs—the sum of the officially unemployed plus those not in the labor force but wanting to work—has declined from 11.2 million to 9.6 million. The number of workers drawn into employment in excess of the normal growth in the workforce has been running at the equivalent of roughly a half of a percentage point of annual GDP growth. This gap must also eventually be closed if inflationary imbalances are to continue to be contained.

Clearly, the growth in gross domestic product cannot exceed the sum of growth in structural productivity and in the working-age population indefinitely. Market pressures must eventually emerge that work to contain such unsustainable growth.

The process of containment may already be significantly advanced. Increasing demand for financing capital goods relative to domestic savings, a reflection of the previously cited

imbalances, has apparently been exerting marked upward pressure on real long-term market interest rates, especially as economies abroad strengthen.

The measurement of real yields, that is, nominal interest rates less expectations of inflation over the maturity of a debt instrument, is inevitably imprecise. It depends, of course, on estimates of inflation expectations, which are very difficult to accurately pin down. But judging by yields on U.S. Treasury inflation-indexed securities, the real riskless interest rate has risen about half a percentage point for ten-year maturities since late 1997. Private long-term real rates have apparently risen even more. The spreads of corporates against Treasuries have widened significantly for investment-grade and, especially, high-yield debt over this period. As a consequence of these higher real interest rates, the ratio of net worth to income for the average household is already lower than it was earlier this year.

We do not have enough experience with technology-driven gains in productivity growth to have a useful sense of the time frame in which market pressures contain demand. Moreover, it is not clear as yet how much cumulative impact the rise in real long-term interest rates over the past two years will have on future demand.

Going forward, the Federal Reserve must monitor not only this response, but also the evolving capacity of our economy to meet higher levels of demand. Maintaining balance between these forces will be essential to preserving the stable price environment that has provided a firm foundation for this period of extraordinary innovation and progress in the U.S. economy.