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Testimony by

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Something special has happened to the American economy in recent years.

An economy that twenty years ago seemed to have seen its better days, is displaying a remarkable run of economic growth that appears to have its roots in ongoing advances in technology.

I have hypothesized on a number of occasions that the synergies that have developed, especially among the microprocessor, the laser, fiber-optics, and satellite technologies, have dramatically raised the potential rates of return on all types of equipment that embody or utilize these newer technologies. But beyond that, innovations in information technology--so-called IT--have begun to alter the manner in which we do business and create value, often in ways that were not readily foreseeable even five years ago.

As this century comes to an end, the defining characteristic of the current wave of technology is the role of information. Prior to this IT revolution most of twentieth century business decisionmaking had been hampered by limited 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 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 maintain quality control and 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 recent

years' remarkable surge in the availability of real-time information has enabled business management to remove large swaths of inventory safety stocks and worker redundancies, and has armed firms with detailed data to fine-tune product specifications to most individual customer needs.

Moreover, information access in real-time--resulting, for example, from such processes as checkout counter bar code scanning and satellite location of trucks--has fostered marked reductions in delivery lead-times on all sorts of goods, from books to capital equipment. This, in turn, has reduced the relative size of the overall capital structure required to turn out our goods and services.

Intermediate production and distribution processes, so essential when information and quality control were poor, are being bypassed and eventually eliminated. The increasing ubiquitousness of Internet web 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.

Economists endeavor to describe the influence of technological change on activity by matching economic output against measurable economic inputs: quality adjusted labor and all

forms of capital. They attribute the fact that economic growth has persistently outpaced the contributions to growth from labor and capital inputs to such things as technological innovation and increased efficiencies of organizations that are made possible through newer technologies. For example, since 1995 output per labor workhour in the nonfarm business sector--our standard measure of productivity--has grown at an annual rate of about 2 percent. Approximately one-third of that expansion appears to be attributable to output growth in excess of the combined growth of inputs.

Of course, it often takes time before a specific innovation manifests itself as an increase in measured productivity. Although some new technologies can be implemented quickly and have an immediate payoff, others may take years or even decades before achieving their full influence on productivity as new capital is put in place that can take advantage of these creations and their spillovers. Hence, the productivity growth seen in recent years likely represents the benefits of the ongoing diffusion and implementation of a succession of technological advances; likewise, the innovative breakthroughs of today will continue to bear fruit in the future.

The evident acceleration of the process of "creative destruction," which has accompanied these expanding innovations and which has been reflected in the shifting of capital from failing technologies into those technologies at the cutting edge, has been remarkable. Owing to advancing information capabilities and the resulting emergence of more accurate price signals and less costly price discovery, market participants have been able to detect and to respond to finely calibrated nuances in consumer demand. The process of capital reallocation has been assisted through a significant unbundling of risks made possible by the development of innovative financial products, not previously available. Every new innovation has suggested

further possibilities to profitably meet increasingly sophisticated consumer demands. Many ventures fail. But the few that prosper enhance consumer choice.

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 capital equipment are long, firms must undertake capital spending that is adequate to deal with the plausible range of business needs likely to occur after these goods are delivered and installed. In essence, those capital investments must be sufficient to provide insurance against uncertain future demands. As lead times have declined, a consequence of newer technologies, firms' forecasts of future requirements have become somewhat less clouded, and the desired amount of lead-time insurance in the form of a reserve stock of capital has been reduced.

In addition to shortening lead-times, technology has increased the flexibility of capital goods and production processes to meet changes in the demand for product characteristics and the composition of output. This flexibility allows firms to deal more effectively with evolving market conditions with less physical capital than had been necessary in the past.

Taken together, reductions in the amount of spare capital and increases in capital flexibility result in a saving of resources that, in the aggregate, is reflected in higher levels of productivity.

The newer technologies and foreshortened lead-times have, thus, apparently made capital investment distinctly more profitable, enabling firms to substitute capital for labor and other inputs far more productively than they could have a decade or two ago. Capital, as economists like to say, has deepened significantly since 1995.

The surge in investment not only has restrained costs, it has also increased industrial capacity faster than the rise in factory output. The resulting slack in product markets has put greater competitive pressure on businesses to hold down prices.

Technology is also damping upward price pressures through its effect on international trade, where technological developments and a move to a less constrained world trading order have progressively broken down barriers to cross-border trade. All else equal, the enhanced competition in tradeable goods enables excess capacity previously bottled up in one country to augment worldwide supply and exert restraint on prices in all countries' markets.

Because neither business firms nor their competitors can currently count any longer on a general inflationary tendency to validate decisions to raise their own prices, each company feels compelled to concentrate on efforts to hold down costs. The availability of new technology to each company and its rivals affords both the opportunity and the competitive necessity of taking steps to boost productivity. This contrasts with our experiences through the 1970s and 1980s, when firms apparently found it easier and more profitable to seek relief from rising nominal labor costs through price increases than through cost-reducing capital investments.

The rate of growth of productivity cannot increase indefinitely. While there appears to be considerable expectation in the business community, and possibly Wall Street, that the productivity acceleration has not yet peaked, experience advises caution.

As I have noted in previous testimony, history is strewn with projections of technology that have fallen wide of the mark. With the innumerable potential permutations and combinations of various synergies, forecasting technology has been a daunting exercise.

There is little reason to believe that we are going to be any better at this in the future than in the past. Hence, despite the remarkable progress witnessed to date, we have to be quite modest about our ability to project the future of technology and its implications for productivity growth and for the broader economy.

A key question that we need to answer in order to appropriately evaluate the connection between technological innovations and productivity growth is why have not the same available technologies allowed productivity in Europe and Japan to catch up to U.S. levels. While productivity in some foreign industrial countries appears to have accelerated in recent years, a significant gap between U.S. productivity and that abroad persists.

One hypothesis is that a necessary condition for information technology to increase output per hour is a willingness to discharge or retrain workers that the newer technologies have rendered redundant. Countries with less flexible labor markets than the United States enjoys may have been inhibited in this regard.

Another hypothesis is that regulations, systems of corporate governance, trade restrictions, and government subsidies have prevented competition from being sufficiently keen to induce firms in Europe and Japan to take full advantage of the efficiencies offered by the latest advances in information technology and other innovations.

Further investigation will be necessary to evaluate the importance of these possible influences. But at this stage, one lesson seems reasonably clear. As we contemplate the appropriate public policies for an economy experiencing rapid technology advancement, we should strive to maintain the flexibility of our labor and capital markets that has spurred the continuous replacement of capital facilities embodying older technologies with facilities

reflecting the newest innovations. Further reducing regulatory impediments to competition, will, of course, add to this process. The newer technologies have widened the potential for economic well-being. Governments should seek to foster that potential.