

**Invention, Productivity, and the Economy**  
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## **Introduction**

Good evening. It is a pleasure to be here with the New Jersey Technology Council. Tonight I would like to spend some time discussing the role invention and productivity play in the growth of our economy and why this issue is important in the conduct of monetary policy. I would also like to share with you what some recent research tells us about the links between invention and productivity — including some research conducted by our staff at the Philadelphia Reserve Bank. I will conclude with some comments about recent productivity growth and its implications for the economic outlook and monetary policy. The views I share with you today are my own and do not necessarily reflect those of my colleagues on the FOMC or in the Federal Reserve System.

The namesake of this speaker series, Thomas Alva Edison, was arguably the most prolific inventor in American history, having amassed 1,093 patents — a remarkable record and one that still stands today.

Edison broadened the notion of invention. He created a model for modern industrial research, invented modern R&D (research and development), and created the world's first research laboratory in Menlo Park, New Jersey, in 1876. He also understood the business of innovation — possessing that enviable quality of being able to turn a brilliant idea into a successful business. That legacy has inspired innovation and inventive activity for over 100 years and stands as an incredible accomplishment and testament to America's entrepreneurial spirit.

We've clearly seen this innovation and entrepreneurial spirit play out in the tech revolution of the last two decades. Advances in information and communications technology have had dramatic effects on the U.S. economy and how people live and work. When you are my age, these innovations often are most apparent in the activities and practices of your children. When I went to college you maybe took a record player and, perhaps, an electric typewriter and then shared a telephone with the rest of the students who lived on your dormitory floor. Of course, now the minimal requirements include MP3 players, laptops, and cell phones. There are costs, however, other than just

the retail price. For example, none of my kids have landline telephones and when they lose their cell phone, as one did recently, it is next to impossible to contact them.

But technological progress and innovation occur in all fields. We have seen great strides in the development of drugs and medical procedures that improve our health. We also see innovation and productivity gains in service industries. Innovation in financial services has changed how firms and individuals use and access the financial market. Electronic payments, improved access to credit, and new products that enhance the allocation of risk and the efficiency of financial markets are widespread. These innovations lower costs and expand opportunities for individuals and firms. If the truth be known, I am not sure any of my children have ever been inside a bank, even though they use banking services.

All of these innovations, both technological and otherwise, drive long-run productivity growth in our economy. But what does this have to do with monetary policy?

### **The Importance of Productivity for the Economy and Monetary Policy**

The output of the economy is primarily determined by the amount of labor and capital it employs, and how productive that labor and capital is in producing goods and services. Improvements in technology or processes that allow the same amount of labor and capital to produce more output means that the economy's productivity has increased. Over time, the economy's output will grow if we have growth of labor, capital, or productivity — or some combination of them.

But when we ask whether people's standard of living is improving over time, we really should look at whether the economy's output is growing on a per capita basis. Improvements in the standard of living basically arise from increases in productivity. Over the long run, higher productivity growth will mean a higher trend rate of economic growth — and higher living standards for the nation's citizens.

The Federal Reserve's goals for monetary policy, as established by Congress, are to seek price stability, maximum sustainable economic growth, and moderate long-term interest rates.

From my perspective, price stability is and should be the primary focus of monetary policy. Sustained inflation is ultimately a monetary phenomenon, and the Federal Reserve is our nation's central bank and monetary authority. Thus achieving and maintaining a stable price level is uniquely the Fed's responsibility. There is no other agency or policy arm of the government that can deliver on this goal. In addition, achieving price stability supports the other two goals.

Price stability works to promote moderate long-term interest rates in two ways. It reduces the level of compensation built into long-term interest rates to make up for the loss of purchasing power due to inflation. It also reduces the need for interest rates to include an additional risk premium for investors bearing inflation risk that arises from inflation volatility.

In terms of the overall economy, maintaining a stable price level allows the economy to function in a more efficient and thus more productive fashion. If people and businesses don't have to worry that the purchasing power of their money will erode because of inflation, they won't have to divert resources from productive activities to conserve their money holdings or to hedge the risks of inflation or deflation. Stable prices also make it easier for households and businesses to make long-term plans and long-term commitments, since they will know what the long-term value of their money will be.

Price stability also promotes efficiency in product markets. In a market economy, prices give signals about the relative supplies and demands of goods and services. With a stable price level, changes in prices can easily be recognized as changes in relative prices. With price signals undistorted by inflation, individuals and businesses are able to make better decisions about where to allocate their resources. Thus, price stability helps a market economy allocate resources efficiently and operate at its peak level of productivity — and therefore its maximum sustainable rate of economic growth.

In short, price stability is not only a worthwhile objective in its own right. It is also the most effective way monetary policy can contribute to economic conditions that foster our other two objectives: maximum employment and moderate long-term interest rates.

In that context, I must add that while price stability enhances the economy's ability to achieve its maximum potential growth rate, monetary policy plays no role in determining what that growth rate is. In the long run, the economy's growth rate largely reflects two factors. The first is the growth rate of the labor force, which is determined by demographic factors like the birth rate, age distribution, and immigration. The second is the growth in the productivity of the labor force, which depends on both physical and human capital and incentives for research and innovation. Monetary policy cannot be used to achieve a long-run growth rate that is inconsistent with these economic fundamentals.

Monetary policymakers, nonetheless, are very interested in tracking the growth of productivity over time, and in monitoring whether changes in reported measures of productivity are merely the result of short-term economic fluctuations or are instead signaling a shift in longer-term trends in productivity. A better understanding of the factors that lead to changes in productivity growth helps policymakers sort out questions such as the level of the underlying inflation-adjusted, or real, interest rate. Doing so helps policymakers more accurately assess the short-term and long-term outlooks for economic growth, inflation, and interest rates and provides important information for the determination of appropriate policy.

### **Factors Affecting Productivity**

Economists have been studying productivity for a long time, and I don't intend to summarize all of that work for you today. But some recent research has underscored the importance of innovation and invention in raising productivity, both in cross-country studies and in analyses of differences in productivity across geographic areas or across industries within the U.S.

A 2001 study of 16 OECD (Organization for Economic Cooperation and Development) countries — including the U.S., Canada, Japan, and 13 European countries — examined the effects on productivity growth of R&D spending of various types, including domestic businesses' R&D, foreign R&D, and government and university R&D. The results show a significantly positive impact of business R&D spending on productivity growth and indicate that there are substantial spillovers from business R&D to the economy as a whole.<sup>1</sup>

This study also found very high and significant effects of foreign R&D spending on productivity growth. The authors concluded that this underscores the importance of ensuring the openness of a domestic economy to foreign technologies. This makes sense because knowledge and technology do not necessarily recognize national boundaries, so R&D that leads to new products and improvements in productivity is often reflected around the world — particularly in those countries whose markets are more open to international trade and investment.

The effect of government and university R&D spending on productivity growth was also positive and significant, but university spending had a larger impact. The authors attributed this to the fact that universities provide basic knowledge to industries which can be used to make technological innovations. Overall, this study of OECD countries underscores the importance of R&D for productivity growth and thus economic growth.

In the U.S., there has been much research on the role information technology (IT) played in the increase in productivity growth in the last half of the 1990s. Recent work by Federal Reserve Board staff on productivity in six sectors of the economy finds that IT investment has played a significant role in productivity growth since 2000 as well.<sup>2</sup> However, this study also finds a lot of differences in productivity growth across the economy's various sectors, as well as differences among these sectors' contributions to the nation's overall productivity growth.

Other researchers studying the U.S. have found that labor productivity is higher in states with denser employment.<sup>3</sup> For example, a 1996 study found that New Jersey had the highest output per worker at the time and ranked third in terms of employment density. The authors attributed their results to the importance of what economists call “agglomeration economies” — the efficiency and cost savings firms enjoy from being close to suppliers, workers, and customers — which increase with the density of a state's or city's population or employment.

### **Innovation and Knowledge Spillovers**

To a large extent, innovation is enhanced through the exchange of ideas among individuals, which economists call “knowledge spillovers.” Work by Philadelphia Fed economists points out that cities still serve as centers of creativity and innovation, even though they are no longer centers of manufacturing. Since cities are more densely populated than rural areas, they are well-disposed to exploit knowledge spillovers, which increase the productivity of local investments in R&D. The presence of knowledge

spillovers is an example of the agglomeration economies that help explain the variations we observe in states' productivity. Furthermore, by increasing the rate of innovation, these knowledge spillovers are an important driver of economic growth in today's economy.

Another factor that influences the magnitude of knowledge spillovers is the competition inherent among nearby innovating firms. Competitive local environments foster the introduction of new methods and new products. In addition, when local economies are competitive, the innovations of local firms are rapidly adopted and improved by neighboring firms. For example, one company's innovation may stimulate a flood of related inventions and technical improvements by other companies.

The latest information about technological and commercial developments is often valuable to firms in the same industry, but only for a short time. Thus, firms benefit when they set up shop as close as possible to such sources of information. This is why — for example — we see semiconductor firms locating their R&D in a place like Silicon Valley. The same thing goes for what we refer to as the Route 128 corridor around Boston and the Research Triangle in North Carolina.

Our region also has a few local high-tech hot spots. Both New Jersey's pharmaceutical and information and communication technology (ICT) industries, as well as Greater Philadelphia's biotech and medical research industries, are testaments to this phenomenon. Indeed, in the three-state area of New Jersey, Pennsylvania, and Delaware the majority of R&D — 56 percent — is in the life sciences and a third of that amount is in medicine alone.

While it is difficult to measure knowledge spillovers, they do sometimes leave a paper trail in the form of patented inventions — which is one of the outputs of R&D spending. While data on patents imperfectly reflect innovation, they may be the best available measure of inventiveness. For an invention to be patented, it must be useful and novel. It must represent a significant extension of existing products.

Data from the U.S. Patent Office show that annual applications for patents increased dramatically between the mid-1980s and the mid-1990s. The top category for New Jersey is drug patents — as it is for the nation — but New Jersey inventors also obtain a disproportionate share of patents in communications equipment and electronics. For New Jersey as a whole, the state's inventors obtained patents at a higher rate than the national average. In fact, over the last decade, four of the top 50 U.S. metro areas with the highest per capita patent activity are in the Garden State. They are Middlesex, Newark, Monmouth-Ocean, and Trenton. The Trenton metro area — which includes Princeton and all of Mercer County — is impressively ranked fifth nationally in patents per capita.

### **What Drives Inventive Activity?**

What drives inventive activity? Because inventions often lead to innovations in technologies used by businesses, which ultimately can raise productivity growth, it would

be helpful to know what factors are important in driving inventive activity. Research conducted recently by Philadelphia Reserve Bank economists examines this issue by investigating the relationship between inventive output — as measured by patents per capita — and a variety of inputs for a cross-section of about 280 U.S. cities in the 1990s. The inputs included private R&D, academic R&D, and other government-supported R&D, as well as human capital.<sup>4</sup>

I want to highlight four of the most important findings from that research.

First, while population density is related to innovative activity, it is important to recognize that the presence and quality of local human capital is critical for innovation. In this study, the percent of the population with a college education made the largest contribution to raising the number of patents per capita in a metro area. This is a “knowledge economy” and highly trained and highly skilled workers are critical, not only to their individual success, but to the inventiveness and productivity of the economy as a whole.

As I have already suggested, research and development is also critical in producing inventive output. Although this study finds that the local amount of private and academic R&D spending contributes to local inventiveness, the effects are modest in comparison to the importance of education. What’s more, the effect of government R&D spending at the local level on inventive activity is very small relative to other types of R&D spending.

The third interesting finding is that those locales that have many smaller companies, rather than a few very large ones, seem to be more productive in terms of patenting or inventiveness. We would like to know more about why this is the case. Is it because more competition for workers among firms improves workers’ incentives to produce patents? Or is it because smaller establishments imply that start-ups are a higher share of local businesses? Our researchers are pursuing additional data to try to disentangle these hypotheses.

Finally, it is worth noting that one important source of a drag on a city’s inventive output is the share of the workforce employed in local government. The larger the share of a city’s employment in local government, the lower the city’s patents per capita.

The authors suggest that their findings tell us something about how policymakers interested in promoting the growth of new technologies should order their priorities: Work first on developing, attracting, and retaining human capital for the community — nothing is more critical for innovation and inventive activity. Second, encourage and support research and development in the private sector and the academic community.

The study’s results are consistent with the view that denser communities allow workers and firms to match up more easily and more productively.<sup>5</sup> Policymakers should avoid policies that interfere with the marketplace’s optimal allocation of resources. Onerous regulation in the labor market could inhibit the formation of new firms or competition for employees. Either of these would impede the market’s inherent efficiencies.

Of course, inventive outputs such as patents are an intermediate input in explaining the ultimate production of new goods and services. But as I indicated earlier, other research shows that higher productivity – and therefore higher economic growth – is positively related to a more highly educated population (i.e., more human capital), higher job density, and increased spending on R&D. Consequently, it seems reasonable to conclude that improving our ability to invent things will improve our ability to increase productivity and economic growth.

### **Future Productivity Growth and the Economic Outlook**

Let me now shift gears and return to how rapidly productivity is likely to grow going forward, and what that implies about the outlook for the economy.

As you know, in recent years, productivity growth has slowed from its very rapid pace in the last half of the 1990s. Although there continues to be much uncertainty about how much of the recent slowdown in productivity growth will prove to be transitory and how much will prove to be persistent, my own view is that trend productivity growth will turn out to be only slightly below 2 percent. And that will mean trend economic growth over the next few years is likely to be close to 2-3/4 percent, slower than the more than 3 percent growth we saw in the late 1990s but not as slow as some economists are forecasting.

The sustainable or long-run trend growth rate of the economy is an important benchmark in calibrating the stance of monetary policy. In general, economies that grow faster exhibit real, or inflation-adjusted, interest rates that are somewhat higher than those of slow-growing economies. Monetary policymakers must be cognizant of that fact in setting the target for the fed funds rate. Failure to do so would likely result in the creation of either too much or too little liquidity, leading to too much or too little inflation or perhaps even deflation.

Thinking about monetary policy in this way is useful in the context of the near-term outlook for the economy and understanding policy actions over the last several months. I have seen several headlines in the last week that suggest the FOMC has changed its approach to monetary policy or that our decision to reduce the fed funds rate target represented some kind of fundamental break with the approach to policy we have been pursuing over the last year or so. I believe that is a mistaken perception.

Over the past year, which is the first year I have participated in monetary policy decision-making, I believe the FOMC has followed a consistent approach to monetary policy and that the recent decision to reduce rates was reached by applying that same approach. The goals of monetary policy include both price stability and sustainable economic growth. As I have already argued, ensuring price stability is probably the single most important thing the Federal Reserve can do to promote long-run sustainable growth. The Committee's objective at each meeting is to set the target federal funds rate at a level that will support these long-term goals.

The influence of monetary policy on inflation and growth occurs with a lag. Consequently, the FOMC must always be forward-looking in its decision-making. The Committee must make its decisions on the outlook for inflation and growth based on the economic and financial information available at the time. As new data become available, the Committee may find it necessary to modify its outlook for inflation and/or growth. If that outlook changes, the Committee may decide to adjust monetary policy and alter the fed funds rate target to better align it with our long-term goals. In my view, our approach to policy has been consistent; it is the data and the outlook that have evolved.

Of course, we are always getting new data on the economy. However, monthly statistics are very volatile and are frequently revised. So we must be cautious not to overreact to one economic variable or one number that may look unusually good or bad. To do so would likely lead to undesirable volatility in monetary policy and the economy. However, enough new data and other information can accumulate so that the outlook changes sufficiently for the FOMC to decide that an adjustment of monetary policy, and thus the funds rate target, is warranted. From my experience, I believe this approach to policy has been consistently applied — from when the FOMC chose to stop raising rates in August of 2006 and at every point since, including our decision to reduce rates last week.

This makes it sound somewhat easier than it actually is. After all, the future is inherently uncertain, and some times are more uncertain than others. The economy almost always turns out to be better or worse than the forecast. Moreover, forecasts often vary across individuals — this is apparent in the Philadelphia Fed's Survey of Professional Forecasters and in other private-sector forecasts. Thus the Committee's deliberations entail a lengthy discussion of the outlook and the various members' assessments of how their views are evolving.

So what changed from early August to mid-September to alter my outlook for the economy? Remember that second-quarter growth was a robust 4 percent — a rate well above trend. Manufacturing output was rising, employment growth appeared to be strong and, as a consequence, personal income also appeared to be strong. Consumers and businesses were continuing to spend and, despite the weakness in the housing sector, the fundamentals seemed to be in place for moderate growth and for the drag of housing to gradually dissipate.

But July and August brought some additional information that cast doubt on that outlook. In early September, the August employment report contained some surprises. It reported an employment decline of 4,000 jobs. My own reaction was to take that number with a grain of salt because August is a tough month to estimate because of back-to-school effects. The August job losses partly reflected a loss of 28,000 jobs in local government education. More troubling for the outlook, in my mind, was the downward revision to both June and July employment gains.

While the unemployment rate remains low, the softening of employment gains in the early summer suggests that the labor market may not be quite as tight or as robust as we

previously thought. If so, then it may have a dampening effect on income and consumption growth in the months to come. Having said that, I would not be entirely surprised if employment growth rebounded. Nevertheless, a softening labor market is a factor in the revision to my outlook.

Incoming information showing a continuing sharp decline in house prices and weak home sales also contributed to the downward revision to my outlook. The cumulative information on the housing market over the last few months has suggested that the recovery in residential construction is likely to be delayed until later in 2008 than many forecasters originally thought.

Finally, the turbulence in the financial markets has created additional uncertainty. While there is little direct evidence that the financial disruptions have significantly affected the broader economy, that certainly is still a real possibility. One source of that risk is that consumers and businesses may choose to delay or defer spending plans until the future becomes a little clearer. In addition, the general tightening of credit conditions, if persistent, can aggravate and possibly further delay the recovery in housing and further dampen both consumer and business spending.

Thus the pace of economic activity is likely to be somewhat slower in the next few quarters than I expected earlier. A slower economy means that real interest rates must decline to bring about the appropriate adjustments to restore growth. In recognition of this, I believe last week's action to lower the fed funds rate target was appropriate.

I would also point out that inflation through the spring and early summer seemed to moderate and inflation expectations appeared to be stable. While I did not and do not take that evidence as a sign that inflation is no longer a risk, it was encouraging. Had this not been the case, the monetary policy decision, in my view, would have been much more difficult.

It is important to understand that the economy is expected to grow more slowly in the coming months, despite last week's decision to reduce rates. Therefore, I will not be surprised to see weaker statistics making headlines. But weaker numbers will not lead me to revise my outlook or my view of the appropriate funds rate target, unless they are much weaker than already anticipated and accumulate sufficiently to generate another downward revision in my outlook.

Last week's funds rate decision was made in anticipation of a slower economy in the coming few quarters. Let me remind you that the U.S. economy has a history of being remarkably resilient. Even though I expect the economy will slow somewhat in the near term, there is also the possibility that growth will rebound more quickly than is now anticipated. If so, and the outlook is revised upward, monetary policymakers will have to reassess the appropriate level of the fed funds rate target.

## **Conclusion**

In closing, I want to stress that there are risks associated with the decision to reduce rates. One risk is that we may exacerbate moral hazard and encourage inappropriate risk-taking. It should be clear that that is not our intention. As I have said, our focus is on the broader economy and its outlook. It is not, nor should it be, the role or responsibility of monetary policy to rescue investors or borrowers from the outcomes of their financial choices. While it sometimes seems an attractive option to soothe investor concerns and soften losses with changes in monetary policy, it is bad for the economy and our financial institutions in the long run. Such a practice encourages excessive risk-taking, and it distorts the allocation of resources within the economy.

We will also have to remain vigilant on the inflation front. The reduction in the funds rate runs the risk of higher inflation and expected inflation in the future. While the inflationary signs this summer have been encouraging, I do not think we are in a position to be sanguine. If inflation begins to creep up or expectations of future inflation rise in the coming months – which is a risk given our decision to cut rates – the outlook will be affected and policy may have to be adjusted. To me, these risks highlight and reinforce my view of the value of a clearly articulated inflation objective. A public commitment to such an objective in this environment would contribute substantially to ensuring that inflationary expectations remain firmly anchored.

In the end, monetary policy must be forward-looking. It should depend on the outlook for inflation and economic growth, and it should not seek to target the prices of individual goods or assets. It must resist the temptation to respond to short-term, transitory disturbances, unless they have a significant impact on our longer-term objectives.

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### Endnotes

<sup>1</sup> D. Guellec and B. van Pottelsberghe de la Potterie, “R&D and Productivity Growth: Panel Data Analysis of 16 OECD Countries,” OECD Science, Technology and Industry Working Papers 2001/3, OECD Publishing (2001).

<sup>2</sup> See Carol Corrado, Paul Lengermann, Eric Bartelsman, and J. Joseph Beaulieu, “Sectoral Productivity in the United States: Recent Developments and the Role of IT,” Finance and Economics Discussion Series 2007-24, Federal Reserve Board (2007).

<sup>3</sup> See Antonio Ciccone and Robert Hall, “Productivity and the Density of Economic Activity,” *The American Economic Review* (1996), pp. 54-70.

<sup>4</sup> See Gerald Carlino, Satyajit Chatterjee, and Robert Hunt, “Urban Density and the Rate of Invention,” *Journal of Urban Economics* (2007), pp. 389-419

<sup>5</sup> See Robert Hunt, “Matching Externalities and Inventive Productivity,” Working Paper 07-7, Federal Reserve Bank of Philadelphia (2007).