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Evaluating McCallum's Rule For Monetary Policy

*Dean Croushore and Tom Stark**

Some economists have proposed that the Federal Reserve follow a rigid rule for conducting monetary policy. A policy rule is a formula that tells the Fed how to set monetary policy. For example, in 1959 Milton Friedman argued that the Fed should increase the money supply a constant 4 percent each year to eliminate inflation and avoid destabilizing the economy. More recently, other economists have identified an additional benefit: a rule can eliminate the inflationary bias that could occur when discretionary monetary policy is used. Under a discretionary policy, decisions are made on a case-by-case basis.

But economists don't agree on how the economy works or on how monetary policy affects the economy. This lack of consensus makes the construction of a policy rule very difficult. A rule that works well in one model of the economy may not work well in others. But do different beliefs about the economy necessarily imply that no rule works in all reasonable models of the economy? Or is it possible to find a rule to guide monetary policy that works fairly well for many different models?

In a series of recent papers, Bennett McCallum of Carnegie-Mellon University proposed a rule that seems to work well in a variety of models. McCallum's rule targets nominal GDP (the dollar value of output in the economy) by setting the growth rate of the money supply (more precisely, the monetary base, which con-

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sists of bank reserves plus currency in circulation). The rule would allow the economy to expand at its normal pace and also eliminate inflation.

According to the rule, monetary policy must adjust whenever nominal GDP differs from its target. For example, when nominal GDP is below target, the Fed should stimulate the economy by increasing money growth. Eventually nominal GDP will grow faster and return to its target level.

How well does McCallum's rule work? In addition to McCallum, John Judd and Brian Motley at the San Francisco Fed have done research on McCallum's rule, as have Gregory Hess, David Small, and Flint Brayton at the Federal Reserve Board of Governors. These studies, which follow the same procedures we use later in this article, show that the rule may work well in very different economic models, though the Hess-Small-Brayton study finds some problems with it. Most of the studies suggest that if the rule had been in place historically instead of the discretionary policy the Fed actually followed, inflation would have been significantly lower and real output about the same as actually occurred. In one article, McCallum even suggests that using the rule could have prevented the Great Depression! But all of these studies draw upon economic models designed solely for the purpose of evaluating the rule.

The main purpose of this article is to expand the set of economic models on which McCallum's rule has been tested. In particular, we examine economic models developed for purposes other than testing McCallum's rule. If the rule does well in these models, such evidence will be more convincing than finding that the rule works well in models designed specifically to test it.

The most important criticism of the research on McCallum's rule is based on the work of University of Chicago economist Robert Lucas. Lucas argues that people's behavior is likely to be different when there is a change in policy, such as the change from discretion to a rule. Consequently, the results of all these studies, including ours, must be taken with a grain of salt: we can never be sure about the effects of a major policy change like this, because we don't know how people's behavior will change. All the studies on McCallum's rule, including this one, assume that the equations that describe people's behavior remain unchanged when policy changes. Unfortunately, no reasonable models of monetary policy yet exist that can deal fully with behavioral changes in response to policy changes, though there is much research under way.

EVALUATING THE BENEFITS AND COSTS OF MCCALLUM'S RULE

Why do economists think a rule for monetary policy is a good thing? Some economists, like Milton Friedman, think that when the Fed follows a discretionary policy it tends to react too slowly. For example, when a recession starts, the Fed may increase the growth rate of the money supply to increase economic activity. But monetary policy takes effect with a long and variable lag, so by the time the faster money growth has an effect, the economy may already be recovering, and the increased growth just leads to too much stimulus and higher inflation.

More recently, economists, including McCallum, have suggested that when monetary policy is conducted without a formal rule, policymakers have a tendency to pursue an inflationary monetary policy.[1] But if they were bound to following a rule, inflation would be lower.

What types of rules are reasonable? One type of rule would have the Fed set monetary policy without regard to economic conditions.

[1]For a useful summary of this issue, see the 1985 article by Herb Taylor in this *Business Review*.

Friedman's 4 percent money-growth rule is an example of such a nonactivist rule. But it is also possible to design rules that permit the Fed to respond to economic conditions. Activist rules include a rule that uses the federal funds interest rate, suggested by John Taylor of Stanford University; a rule that uses forecasts of future nominal income, developed by Robert Hall of Stanford University and Gregory Mankiw of Harvard University; and a rule that uses the M2 money stock to target nominal GDP, proposed by Martin Feldstein of the National Bureau of Economic Research and James Stock of Harvard University. We will evaluate McCallum's rule because it is the most widely known activist rule, but our techniques could be used to evaluate any of these other rules.

What are the potential benefits of setting monetary policy using McCallum's rule? Because the rule is designed to give better long-run performance than the discretionary monetary policy that was actually followed over time, we expect the rule's biggest impact to be a lower average simulated inflation rate than the actual average inflation rate. Using the rule should drive inflation to zero. The rule may also reduce short-run variability in the economy by forcing the Fed to respond to economic conditions in a systematic, rather than discretionary, manner.

Following the rule also has several potential costs. Our main concern is that the rule may generate economic instability. Instability occurs if the rule makes monetary policy respond too much, pushing the economy in one direction in one quarter, then the opposite direction in the next. This type of instability leads to explosive fluctuations in the key macroeconomic variables, which is clearly bad for the economy.

A second potential problem with following a rule is policymakers' loss of discretion. Policymakers often claim that the economy faces many unique circumstances and that only their expertise and judgment produce the right decisions. Thus they prefer the flexibility of exercising discretion rather than following a rule.

To examine the benefits and costs to the economy of having monetary policy guided by McCallum's rule, we proceed in the following way. First, we choose several economic models, which are simply sets of equations that describe the relationships among major economic variables. It's common to allow for the possibility that the equations cannot account for all the potential ways in which the variables may be related. Therefore, each equation may be affected by random influences that, from time to time, will cause it to fail to explain the movements that we observe in economic variables like real GDP and the price level. In keeping with tradition, we call these random influences economic shocks. For example, oil price increases during the mid-1970s resulted in unexpectedly higher inflation, and economists viewed these increased prices as shocks to the equation that explains inflation in many macroeconomic models.

By letting a computer pick random shocks to attach to each equation in a model over the period 1963-93, we simulate how the economy would have behaved over this period if McCallum's rule had determined monetary policy.[2] The computer then solves the equations of the model and generates simulated values for real GDP and the price level over time.

There's one problem with this procedure: the computer may pick an unrealistic set of shocks over time. If it does so, our simulated values of how the economy would have performed with McCallum's rule will not be comparable with the actual historical values of real GDP and the price level. To guard against that

[2]Our models use quarterly data, so the computer picks four shocks each year. The shocks are chosen so that they are as variable, on average, as the actual shocks to the economy.

possibility we simulate each model 500 times. Each time, we allow the computer to choose a different set of shocks, and corresponding to each of these, we generate a simulated path of real GDP and the price level.

Finally, we use the simulation results of each model to examine how the economy would have behaved over the period 1963–93 if McCallum's rule had actually been guiding monetary policy. To do that, we use our 500 simulations to construct ranges of simulated values for real GDP and the price level, in each model, ignoring the largest and smallest 5 percent of the 500 simulated values at each date. We compare these ranges to the actual values of real GDP and the price level.

The key element of simulations with McCallum's rule is the monetary response factor, which determines how much money growth must change when nominal GDP deviates from its target. If the monetary response factor is large, money growth will respond a lot when nominal GDP is off target by a given amount. A smaller monetary response factor will mean a smaller policy change. Having a large monetary response factor is not necessarily a good idea. Our research suggests that if the monetary response factor is too large, it will induce an explosive reaction, or instability, in the economy. When nominal GDP is off target, monetary policy has too strong an effect, and the economy responds by moving too far in the opposite direction. On the other hand, a monetary response factor that is too small means that policy doesn't affect the economy much. There seems to be a range of ideal values for the monetary response factor. (See *Technical Details on McCallum's Rule.*)

THE MODELS

We'll examine three macroeconomic models to evaluate McCallum's rule.[3]

Keynesian Model. Ben Friedman of Harvard University developed a Keynesian model of the economy in the 1970s. In the model, four equations determine the main macroeconomic variables: (1) real GDP growth depends on the growth of government expenditures and on changes in the long-term interest rate and import prices; (2) inflation depends on real GDP growth and changes in import prices; (3) money demand growth depends on real GDP growth and the change in the short-term interest rate; and (4) the long-term interest rate is related to the short-term interest rate. In the absence of shocks, real GDP eventually returns to a normal level, called potential GDP, that does not depend on monetary policy.[4]

McCallum's research suggests using a monetary response factor of 0.25, because that value worked well in his studies. This means that the Fed should increase the growth of the money supply by 0.25 percent for every 1 percent that nominal GDP falls below its target. We simulate the model 500 different times, each time using a different set of randomly determined shocks to the equations of the model over the period 1963-93 (Figure 1). For real GDP, we plot (on a logarithmic scale) the actual value of real GDP over this period, the level of potential GDP, the middle value of the 500 simulations at each date, and upper and lower bounds showing the range in which real GDP lies across the 500 simulations, excluding the largest and smallest 5 percent of the simulations (this gives you an idea of how much variability there is across different simulations).[5]

[3]The technical details of all the models, our simulation procedure, and more results beyond those presented in this article may be found in our 1994 working paper.

[4]For consistency, we use the same potential GDP assumptions in all three models, even though that requires us to modify Friedman's model slightly. We use the potential GDP series developed at the Federal Reserve Board for use in the P* model.

[5]The logarithmic scale is used so that when a variable grows at a constant rate, the figure shows a straight line.

Technical Details on McCallum's Rule

McCallum's rule contains three major parts: (1) the target for current growth of nominal GDP; (2) a moving-average adjustment for changes in velocity (that is, changes in money demand relative to nominal GDP); and (3) the difference between the target and actual nominal GDP. An equation representing these factors is:

$$\dot{B} = (\dot{P}^* + \dot{Y}^*) - \dot{V} + \lambda\,(X^* - X)/X^*,$$

where B is the monetary base (bank reserves + currency), $\dot{P}^*$ is the target inflation rate, Y^* is the level of potential real GDP, V is the lagged 16-quarter moving average of the velocity of the monetary base, which equals nominal GDP/monetary base, X is last quarter's level of nominal GDP, X^* is last quarter's target for nominal GDP, and λ is the monetary response factor. A dot ($\cdot$) over a variable indicates the growth rate of that variable.

The first part of the rule, $(\dot{P}^* + \dot{Y}^*)$, is the current targeted growth rate for nominal GDP (equal to potential real GDP growth plus the desired inflation rate).[a] This part of the equation says that money growth should equal the targeted growth of nominal GDP, other things being equal. The second part of the rule, $-\dot{V}$, allows an adjustment for changes in money demand. If the relationship between the monetary base and nominal GDP changes, for example, because of new financial instruments, the growth rate of the monetary base will be adjusted accordingly. The last part of the rule, $\lambda(X^* - X)/X^*$, represents proportional feedback to the growth rate of the monetary base from the proportionate gap between nominal GDP and its targeted level.

Here's an example of how the rule might work in practice. The rule is expressed in quarterly terms, but to make the example clearer, we'll change everything into annual growth rates and multiply the monetary response factor by 4. In March 1994, suppose the target inflation rate is $\dot{P}^* = 3$ percent, potential GDP is growing at $\dot{Y}^* = 2.5$ percent, average velocity growth over the past four years was $\dot{V} = -4$ percent, the nominal GDP gap is 0.2 percent, and the monetary response factor is $\lambda = 0.25 \times 4 = 1$, then McCallum's rule suggests a monetary-base growth rate of $(3\% + 2.5\%) - (-4\%) + (1 \times 0.2\%) = 9.7\%$. Over the previous year, the monetary base had been growing about 11 percent, so McCallum's rule suggested that monetary policy needed to be tightened somewhat.

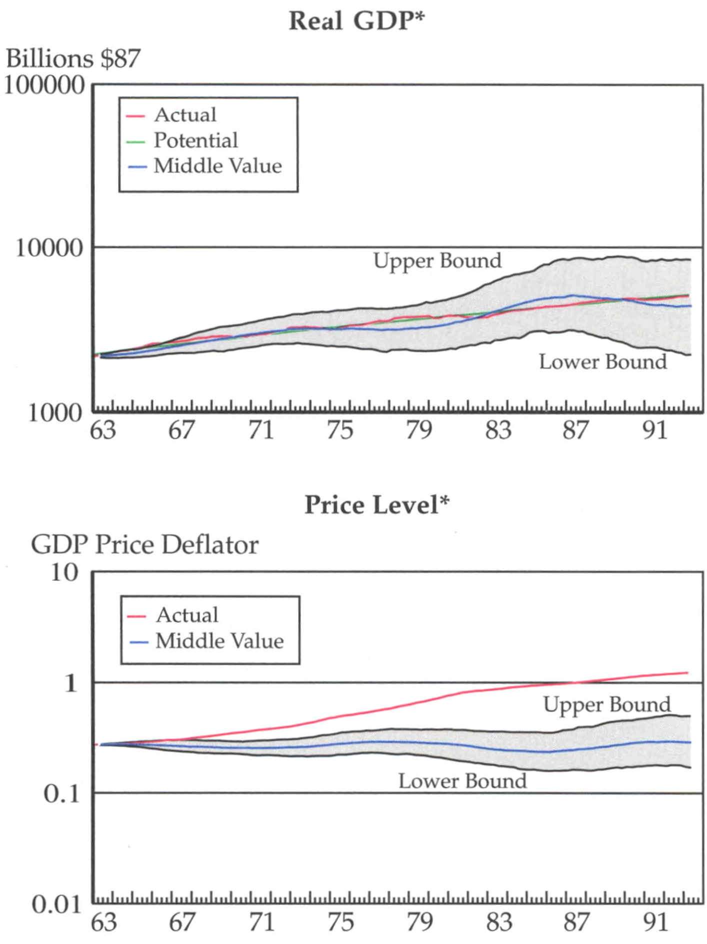
[a]No one knows the exact growth rate of potential real GDP, but many economists estimate that potential real GDP growth is about 2.5 percent. If McCallum's rule is set up with an incorrect growth rate of potential real GDP, a small amount of inflation or deflation could result, since we'd be targeting nominal GDP slightly too high or too low. But such an error is likely to be small.

From the figure you can see that while real GDP appears to be near its potential level, on average, in the simulations, there are large fluctuations above and below potential GDP. These movements correspond to periods of high unemployment, when output is below its potential level, and low unemployment, when output is above its potential level. These fluctuations get larger as time passes, which suggests that there's a problem with using the rule to set monetary policy: it seems to introduce instability into the economy.

The bottom panel of the figure shows the price level over time. As you can see, the rule helps reduce the price level relative to its actual value, which means inflation is much lower on average in the simulations than it was historically. But again, there's a problem of instability as time goes on. We'll discuss this problem in more detail shortly.

FIGURE 1

Keynesian Model Simulations



*Plotted on a log scale

PSTAR+. Herb Taylor at the Federal Reserve Bank of Philadelphia developed the PSTAR+ model in the late 1980s for use in aiding monetary policy decisions. The model is a hybrid between a Keynesian model of the economy, in which changes in short-term interest rates affect output in the short run, and a monetarist model, in which the money supply determines inflation in the long run.

Robert Laurent at the Federal Reserve Bank of Chicago studied the short-run effect of interest rates on output and found that the difference between short-term and long-term interest rates is an important factor affecting output. The long-run effect of the money supply on inflation is based on the P* (pronounced P-star) model developed by Jeffrey Hallman, Richard Porter, and David Small, staff economists at the Board of Governors of the Federal Reserve System. The P* model predicts future inflation using the monetarist theory that, in the long run, the price level is proportional to the money supply.

In addition to equations representing these ideas, the model includes an equation that determines the relationship between the short-term interest rate and the money supply and an equation that determines the long-term interest rate. In the original model, the Fed used changes in the federal funds rate when it wanted to change monetary policy. We modify this slightly to accommodate McCallum's rule, so that the Fed uses changes in the monetary base, which in turn affect the federal funds rate. When the Fed increases growth of the monetary base, the federal funds rate declines initially. This decline in the short-term interest rate increases the spread between long-term and short-term interest rates, stimulating the economy to produce more output. It also increases money growth, which will lead to higher inflation in the future.

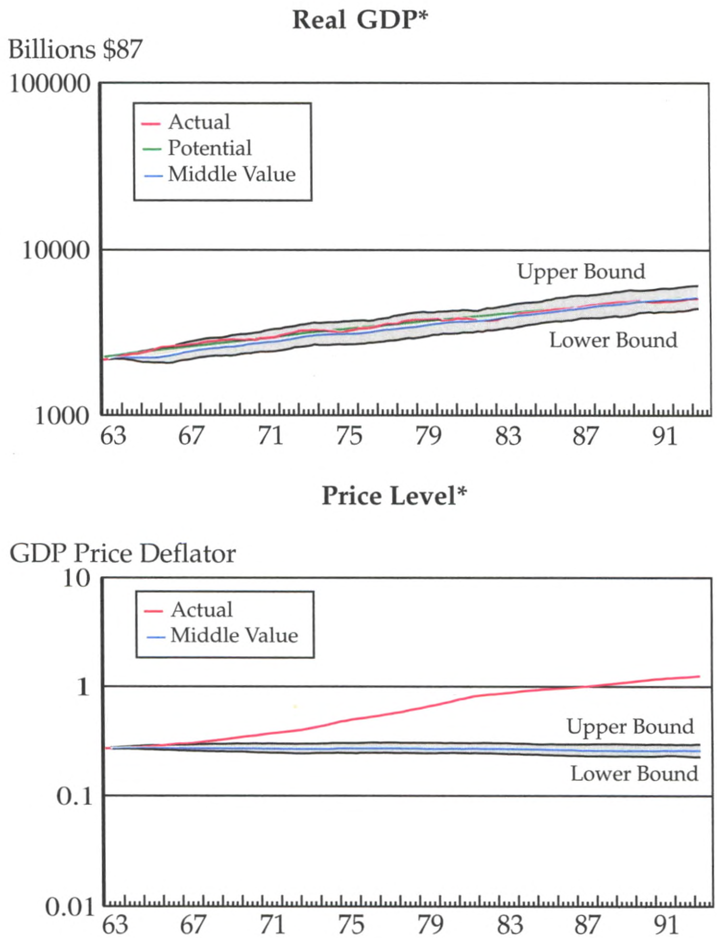
The 500 simulations of this model with a monetary response factor of 0.25 show that McCallum's rule works quite well in stabilizing both real GDP and the price level (Figure 2). The middle path for real output in the economy is quite close to its potential level. And there is little variability along that path, compared with the case in the Keynesian model, as the simulations lie in a quite narrow range. The price level is also stabilized quite well. Inflation is close to zero as a result of using McCallum's rule. And unlike the Keynesian model, there's no sign of instability over time.

Rational Expectations Model. John Taylor of Stanford University developed our third model in 1979. This model assumes that people's expectations about inflation, which affect the demand for output in the economy, are formed using the model itself. The rate of inflation affects the supply of output in the economy because workers are assumed to be locked into fixed nominal wages (for several years) through negotiations with their employers. As a result, higher inflation means firms pay workers less in real terms, so they will hire more workers, earn higher profits, and increase output.

In this model, people's demand for output increases when the Fed increases the growth rate of the money supply, leading to higher output in the short run. In the long run, output returns to its potential level and the inflation rate rises.

FIGURE 2

PSTAR+ Model Simulations

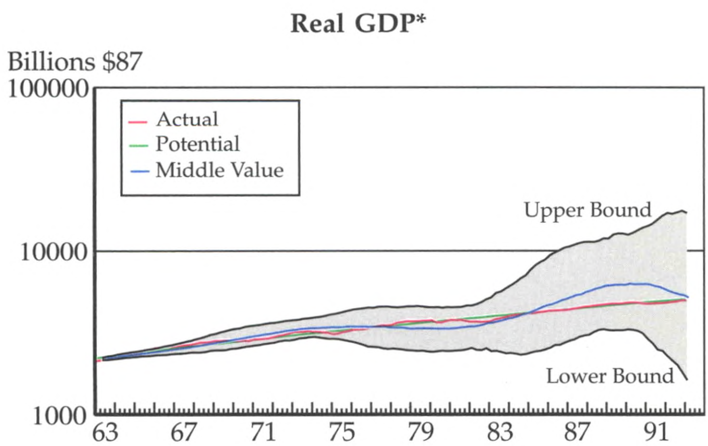


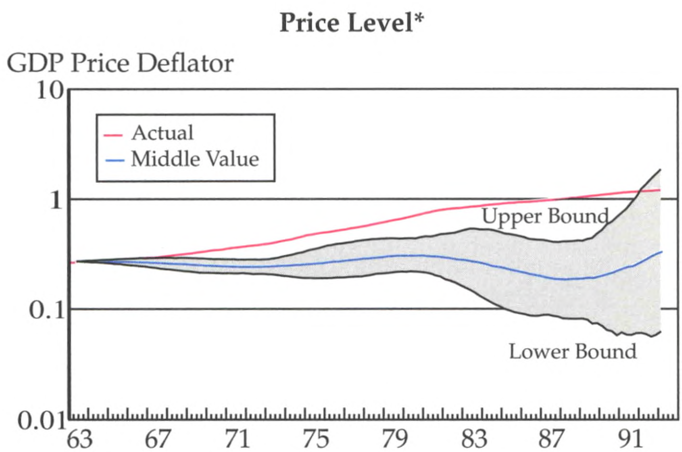
*Plotted on a log scale

Simulations of the model with a monetary response factor of 0.25 (Figure 3) are similar in many ways to those of the Keynesian model. For real GDP, the middle value of the simulations varies around the level of potential real GDP, but with much greater variability than the economy actually had. As time passes, the range of real GDP encompassed by 95 percent

FIGURE 3

Rational Expectations Model Simulations





*Plotted on a log scale

of the simulations gets larger, suggesting a problem of instability. The fact that the middle value and upper and lower bounds show waves also suggests an instability problem. The simulated price level also seems to suffer from instability, but average inflation is much lower than it was historically.

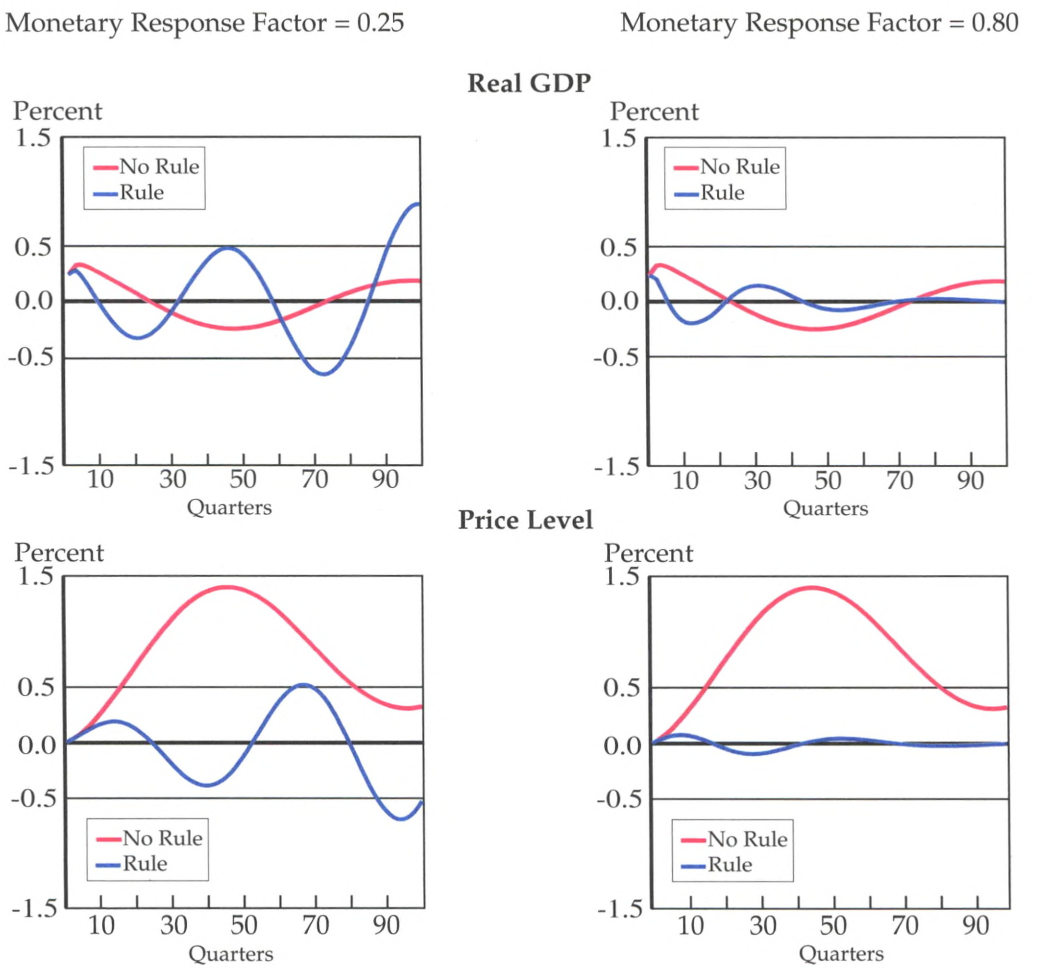
Stability Issues. In all three models, using McCallum's rule seems to be useful, on average. The average level of real output seems to be at about its potential level, while the price level is much lower in the simulations than it was historically. However, only in the PSTAR+ model were both real GDP and the price level stable. In both the Keynesian and the rational expectations models, McCallum's rule seems to introduce instability.

We investigate this matter further by conducting some additional simulations with different values of the monetary response factor. The Keynesian model requires a much larger policy response; the monetary response factor should be about 0.80 instead of 0.25. Such a large value of the monetary response factor means that nominal GDP hits its target very closely. Both real output and the price level are stabilized quite well, and the range of the simulations is quite narrow. This result is perhaps not surprising, since Keynesian models are designed to give government stabilization policies a strong role. If the monetary response factor is low, the range of the simulations becomes larger over time, and the economy is unstable.

We demonstrate the results of our search for better values of the monetary response factor by isolating the economy's response to a particular shock. Suppose there's a spending shock that raises people's demand for goods and services. We look at what happens in the Keynesian model to real GDP and the price level over the 100 quarters following the shock when the monetary response factor is 0.25 and when it is 0.80, compared with the economy's response when McCallum's rule isn't used (Figure 4). In the absence of McCallum's rule, the shock immediately increases real GDP, as firms increase their production to accommodate higher demand. Over time, in the absence of McCallum's rule, output returns to its potential level, but the price level begins to rise. With McCallum's rule and a monetary response factor of 0.25, the figure shows instability in real GDP: it declines more than it would have without the rule, then it rises even more, then it declines even more, and so on. However, when

FIGURE 4

The Proportionate Response of Real GDP and The Price Level to a Spending Shock



the monetary response factor is set to 0.80, not only is the price level stabilized immediately, but real GDP is much more stable. Unfortunately, when the monetary response factor is 0.80, both the PSTAR+ model and the rational expectations model are unstable.

FURTHER ISSUES

Since the size of the monetary response factor is critical in determining whether McCallum's rule leads to instability, is there anything we can do to modify the rule to guarantee stability? One possibility is to argue that certain models are poor representations of the economy. If so, we should eliminate them from consideration in deciding on a rule for monetary policy. But macroeconomists remain divided, and none of these models can be easily eliminated from contention.

Another potential way to eliminate instability is to allow the rule to depend on additional factors. As the rule is currently structured, changes in the monetary base are made proportionally in response to deviations of nominal GDP from its target. But A.W. Phillips long ago recognized that proportional policy responses could be destabilizing and suggested additional feedback based on both the long-term average of the target variable and the current change in the target variable. Incorporating these additional factors into McCallum's rule could eliminate the instability we found.

Another issue relates to the actual use of the rule. Suppose the Fed were to adopt McCallum's rule or use it as a guide to policy. Over time, we would be able to see how the economy reacted to shocks when the rule was in use. The rule could then be refined to find the best level for the monetary response factor. The Fed could even develop a metarule—a rule for changing McCallum's rule.

Just as with all other policy changes, the Lucas critique points out an important limitation to our simulation results. We don't have a good idea of how people's behavior would change if the Fed were to implement McCallum's rule. As macroeconomists develop new theories of behavior, we may be better able to simulate the effects of using McCallum's rule.

Can McCallum's rule be sold to policymakers as a reasonable alternative to discretionary policymaking? Policymakers seem unalterably opposed to nonactivist rules like Milton Friedman's, in which a variable such as the growth rate of the money supply is set once and for all, without regard to the condition of the economy. However, McCallum's rule is an activist one—monetary policy eases during recessions and tightens during expansions. But because so many unique events affect the economy, policymakers seem unlikely to ever give up discretionary policymaking, even for an activist rule. Still, McCallum's rule may help provide some guidance to discretionary policymaking.

McCallum's rule is potentially useful for setting monetary policy. Had the rule been followed over the past 30 years, inflation would have been much lower than it actually was. But the rule can't yet be put into practice, because our research has found that different monetary response factors are necessary to prevent instability with different models.

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Do Education and Training Lead to Faster Growth in Cities?

*Gerald A. Carlino**

Most countries make sustained economic growth a principal policy objective. Although many factors contribute to the growth process, recent research has found that educating workers plays an important role. Individuals invest in education because of expected private benefits, such as higher earnings. But such investments can affect the productivity of others as well as the productivity of the person making the investment. For example, the collaborative effort of many educated individuals in a common enterprise may lead to a higher sustained rate of innovation in the design of products. Such knowledge spillovers provide one justification for subsidizing investment in education.

Recently, some economists have suggested an important link between national economic growth and the concentration of more highly educated people in cities. These economists argue that the knowledge spillovers associated with increased education can actually serve as an engine of growth for local and national economies. They also argue that the concentration of people in cities enhances these spillovers by creating an environment in which ideas flow quickly among people.

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AGGLOMERATION ECONOMIES

For some time economists have understood that the level of productivity is higher in large cities than in less densely populated areas because of agglomeration economies.[1] Agglomeration economies occur when a number of economic enterprises locate near one another. This proximity of firms creates externalities that constitute an important source of a firm's productivity.[2] Recently, economists have suggested that the spatial concentration of large groups of educated people may lead not only to a higher level but also to a faster growth rate of productivity in cities than outside them. The dense concentration of educated people in cities permits a great deal of personal interaction, which, in turn, fosters new ideas, products, and processes that may lead to faster productivity growth for urban firms.

Traditional View. Economists believe that agglomeration economies are important for understanding the development and growth of cities. Other things equal, firms' production costs are lower in large cities than elsewhere because large cities offer access to a variety of specialized business services. As new firms enter a city and the size of the city increases, production costs for other firms in the city are lowered because more specialized labor markets are created and specialized firms are allowed to operate more efficiently. For example, these cost reductions entice other firms to either move to or start up in large cities, leading to further cost reductions because of increased agglomeration.

However, urbanization brings not only greater efficiency but also problems, such as congestion, that eventually balance or outweigh the gains in efficiency that increased urbanization allows. And since costs from congestion eventually offset further agglomeration economies, those economies will not be a source of *continuing* growth for any city. In the long run, as a city becomes more congested, traffic and pollution increase, rents rise, and growth slows down. Thus, economists concluded that in the long run, the link between agglomeration economies and congestion leads to differences in the level of productivity across places but that the *growth* rate of productivity will be the same across places.

New View. Recently, some economists have questioned the traditional view that productivity eventually grows at the same rate across places. Comparisons across countries suggest an important link between productivity growth and increased education. Within a nation, the higher density of population and employment in cities promotes educational spillovers that keep productivity in cities growing indefinitely at a rate greater than that outside cities. If so, rising educational attainment may promote continuing rapid economic growth.

The new view of productivity growth focuses on the development of human capital.[3] Human capital refers to people's stock of knowledge and productive skills. Education is one way individuals add to their human capital.

[1]Unless otherwise indicated, the expression "city," "urban," "urban areas," "metropolitan area," and their adjectives are being used to designate a metropolitan statistical area (MSA). MSAs are geographic areas that combine a large population nucleus with adjacent communities that have a high degree of economic integration with the nucleus.

[2]An externality exists when the economic activity of one firm affects, negatively or positively, the economic activity of another. For example, a positive externality occurs when a beekeeper's bees pollinate a nearby apple orchard. The apple orchard produces more fruit, and the bees are able to get nectar to make honey. Therefore, both beekeeper and apple grower benefit.

For a fuller discussion of agglomeration economies, see Gerald A. Carlino (1987 and 1993).

[3]For more on the new view of productivity growth, see Satyajit Chatterjee, "Making More Out of Less: The Recipe for Long-Term Economic Growth," Federal Reserve Bank of Philadelphia *Business Review,* May/June 1994.

People sacrifice some consumption today while they go to school to improve their human capital. In return, they will receive higher lifetime wages, which will allow them to consume more goods and services in the future. Firms are willing to pay higher wages to educated workers because as people acquire more knowledge, they become better workers, which leads to an increase in output. In addition, formal education may also strengthen a worker's ability to learn on the job, setting the stage for a greater or more rapid accumulation of specific job-related skills. Thus, the current productivity of a worker and his income depend partly on his experience and partly on his education. Economists refer to the accumulation of human capital on the job as learning by doing.

Economists argue that individuals continue to invest in education until the expected return from an additional year of education is balanced by the additional cost of obtaining that year of education. This calculation incorporates only the private returns from education. But as individuals accumulate knowledge, they also contribute to the productivity of many other individuals with whom they have contact either directly or indirectly. Thus, the accumulation of knowledge by any one individual has a positive effect on the productivity of others. This effect is referred to as knowledge spillovers.

Many economists think knowledge spillovers are particularly prevalent in cities, where communication among individuals is extensive. The concentration of people and firms in cities creates an environment in which new ideas travel quickly. Economists have identified two types of knowledge spillovers thought to be important for city growth. The first depends on the concentration of firms in the same industry, and the second on the diversity of firms in a given city.

MAR Spillovers. In 1890, Alfred Marshall developed a theory of knowledge spillovers that was later extended by Kenneth Arrow (1962) and Paul Romer (1986); thus, the name, MAR spillovers. According to this view, the concentration of firms in the same industry in a city helps knowledge travel among firms and facilitates the growth of the industry and of the city. Employees from different firms exchange ideas about new products and new ways to produce goods: the larger the number of employees in a common industry in a given city, the greater the opportunity to exchange ideas. For example, many semiconductor firms have located their research and development facilities in the Silicon Valley because the area provides a nurturing environment where semiconductor firms can develop new products and production technologies. In a 1992 article, Edward Glaeser, Hedi Kallal, José Scheinkman, and Andrei Shleifer noted that Silicon Valley's semiconductor firms learn from one another because "people talk and gossip, products can be reverse engineered, and employees move between firms."

A 1992 article in *Business Week* provides numerous examples of "high-tech hot spots" of rapid growth based on the innovation of new products. Examples include development of lasers in Orlando, Florida; the manufacturing of computers and computer chips in Austin, Texas; the development of biotechnology research and medical technology software in suburban Philadelphia; and the development of medical instruments in Minneapolis.[4] According to this article, "America's most innovative big companies, including Corning, Hewlett-Packard, Intel, and Motorola, have located key facilities in the new-growth areas. The goal is to harvest ideas and talent from universities or startups, a key advantage in a global economy where the first to market wins."

Examples are not limited to the United States. In 1990, Michael Porter cited the Italian ceramics and ski boot industries and the German

[4]*Business Week*, October 19, 1992, pp. 80-88.

printing industry, among others, as examples of geographically concentrated industries that grew rapidly through the continual introduction of new technologies. A recent article in the *Wall Street Journal* cited similar examples in the Emilia-Romagna region of northern Italy. In this region, small, mostly family-run businesses have prospered because of the "highly interwoven nature of the enterprises there....Competitors and suppliers cluster together in small geographical areas."[5] For example, there's the "food valley" around Parma, textile producers at Carpi, and manufacturing of motorcycles around Bologna. According to the article, these businesses have developed ties with local schools and universities that provide "just the right training needed by local firms. Academics and business executives collaborate on research and development ...Technical workers with new ideas...start their own companies, each specialized in a niche."[6] All these factors combined have led to innovations that enable these companies to thrive and compete in the international marketplace.

Many cities, however, such as Akron (tires), Pittsburgh (steel), and Detroit (autos), have declined or stagnated in spite of the advantages that specialization entails.

Jacobs Spillovers. In 1969 Jane Jacobs developed another theory of knowledge spillovers, which stressed the importance of diversity within a city. Jacobs believes that the most important type of knowledge transfer does not depend on the concentration of an industry in a given city but is related to the diversity of industries in a city. In Jacobs's view, industrial variety is more important than specialization for city growth, since an exchange of different ideas in more diversified settings takes place. That is, an industrially diverse urban environment encourages innovation. Such areas contain people with varied backgrounds and interests, thereby facilitating the exchange of ideas among people with different perspectives. This exchange can lead to the development of new products and innovations in methods of production. Jacobs contrasts Manchester, England, in the mid-1850s, which specialized in textiles and eventually declined, with Birmingham, England, which was more diverse and eventually prospered.

There are numerous examples of specific spillovers from one industry to another in large cities. Jacobs notes that a San Francisco food processor with a small but growing business introduced equipment leasing when he was unable to find financing for the equipment he needed to expand production. Edward Glaeser and associates (1992) point out that New York City grain and cotton merchants in need of financial institutions started the financial services industry in that city. While these are interesting examples of knowledge spillovers across industries, economists have recently attempted to find more general empirical support for both the MAR and the Jacobs view of spillovers.

WHAT'S THE EVIDENCE?

According to the theory on knowledge spillovers, differences in education across cities result in differences not only in the level of productivity but also in the growth rate of productivity. A growing body of research examines the importance of educational spillovers on productivity growth, both across countries and across cities within a given country. (See *Educational Spillovers: The Cross-Country Evidence*.) We'll look at the evidence across cities in the United States because educational spillovers are thought to be stronger in cities and because the cross-city findings are easier to interpret than are cross-country results.

Several recent studies have attempted to

[5]Maureen Kline, "Tiny Business Enclave in Italy Stares Down Adversity," *Wall Street Journal*, August 18, 1994.

[6]Kline, *Wall Street Journal*, August 18, 1994.

Educational Spillovers: The Cross-Country Evidence

Recent studies have employed various measures of education to proxy for initial human capital. While some studies have found that education has a positive effect on a nation's growth, the evidence is far from conclusive.

Studies That Found a Positive Effect. Robert Barro found that rates of primary and secondary school enrollment in 1960 significantly affected output growth for a sample of 98 countries during 1960-85. Barro's results are not compelling, however, because he also found that enrollment rates for 1950 and 1970 did not significantly affect growth during this period.

Ellis Tallman and Ping Wang focused on the growth experience of Taiwan to examine the effects of human capital on output growth. They developed an index of labor quality (human capital) by weighting workers according to the level of schooling completed (primary school only; primary and secondary school; and primary, secondary, and higher education). They found that using measures of labor quality improved their ability to account for economic growth in Taiwan during the 1965-89 period.

Studies That Found No Positive Effect. In a sample of 69 countries, Paul Romer (1990) looked at whether the literacy rate in 1960 affected growth over the next 25 years. He found that literacy did not significantly affect output once he accounted for the rate of investment in physical capital.

Ross Levine and David Renelt examined correlations between growth and a variety of variables, including human capital measures, typically employed in cross-country studies. They reported that one could find a positive and significant relationship between educational variables and economic growth. However, once the effects of other variables, such as growth of domestic credit, are taken into consideration, the relationship is not statistically significant.

provide evidence of the importance of educational spillovers for cities.[7] A 1993 study by James Rauch establishes the existence of educational spillovers for metropolitan areas in the United States. Rauch looked at how differences in the average level of schooling across metropolitan areas affect otherwise identical workers. Rauch found that a higher average level of human capital in metropolitan areas has external effects that lead to greater productivity. Using data from the 1980 census, he estimates that in metropolitan areas, each additional year of average education increases productivity anywhere from 2 to 3.6 percent.[8]

In another study, Edward Glaeser and David Maré studied two longitudinal samples that tracked male heads of households from 1968 to 1983.[9] They considered the effects on productivity of formal schooling and on-the-job experience for workers living in cities as opposed to those living outside. Glaeser and Maré found mixed evidence that residing in a city raises the return to schooling, but they did find higher returns to work experience in cities, suggesting that spillovers from learning by doing may be

[7]Robert Lucas (1988) was the first to suggest that the average level of human capital within a city could magnify the impact of individual human capital and lead to increased productivity in cities.

[8]Rauch controlled for gender, race, ethnicity, years of schooling, years of work experience, and occupation. One limitation of Rauch's study is that it provides evidence that the *level* of productivity depends on average years of schooling in metropolitan areas. Rauch does not consider the effect of average years of schooling on productivity *growth rates* in metropolitan areas.

[9]Glaeser and Maré employ data from the Panel Study of Income Dynamics Survey, as well as the National Longitudinal Survey of Youths. In the Glaeser and Maré study, the term city refers to the central city of a metropolitan area.

important. For example, they observed that the wage gap between inexperienced workers and workers with between 20 and 25 years' experience is 12.4 percent higher in cities.

The studies by Rauch and by Glaeser and Maré tried to show that educational spillovers exist in cities. Other studies have looked instead at whether spillovers are best explained by the MAR or the Jacobs theory. A study by Edward Glaeser and associates looked at the employment growth of the six largest industries in each of 170 metropolitan areas during the period 1956-87 and found that within-city industrial diversity is positively associated with employment growth of industries in that city, while the concentration of an industry within a city does not foster employment growth. They interpreted these findings as support for Jacobs's theory that knowledge spillovers seem to be important among rather than within industries.

While the work of Glaeser and associates tends to dismiss the importance of the geographic concentration of a firm's own industry, a 1994 study by J. Vernon Henderson uncovered evidence to the contrary. Henderson looked at employment growth in five different manufacturing industries (transportation, instruments, primary metals, machinery, and electrical machinery) at the county level during 1977-87. Henderson found that, in general, these manufacturing industries benefit both from own-industry concentration (MAR effects) and from the diversity of industrial concentration (Jacobs's effects).

Limitations. One problem with the studies by Glaeser and associates and Henderson is that they used industrial concentration and industrial variety in cities as proxies for educational spillovers. However, industrial concentration and industrial variety within a city may be positively associated with growth of employment because they encompass factors other than educational spillovers that lower production costs. For example, the concentration of similar firms in a city allows any one firm to dip into a common pool of specialized workers or products. Industrial diversity demonstrates how firms benefit from the greater variety and services that large cities offer. In other words, many factors other than knowledge spillovers account for the concentration of economic activity in cities. To the extent that industrial concentration and variety reflect the traditional view of agglomeration, these variables will not be useful in identifying the effects of educational spillovers for city firms.[10]

Another limitation of the studies by Glaeser and associates and Henderson is that they look at employment growth in different cities rather than productivity growth. The problem with using employment growth as a proxy for productivity growth is that employment growth in a city will ultimately be halted by congestion even though productivity continues to grow. If productivity growth does benefit from the geographic concentration of knowledge in cities, the faster growth of productivity in cities would be reflected in relatively faster wage growth for city workers and relatively faster growth of profits for urban firms. Within a given country, people and firms will migrate from areas with slow growth rates of wages and profits to cities where wages and profits are growing faster. But migration into cities with faster-than-average productivity growth pushes up residential and commercial rents in those areas. Congestion costs also increase with population. At

[10]A study by Adam Jaffee, Manuel Trajtenberg, and Rebecca Henderson (1993) avoided some of these problems by looking at data on patents sorted by geographic location as evidence of the extent to which knowledge spillovers (via research and development) are geographically localized. They found that U.S. patents were more likely to come from the same state and city as earlier patents than one would expect based only on the pre-existing concentration of research and development activity. They also found that location-specific information disperses slowly from place to place, making geographic access to that knowledge important to firms.

some point the additional costs of increased city size will exceed the additional benefits of larger size. At this point, population and employment stop growing. But productivity can continue to grow in cities, and productivity grows in cities as a result of ongoing educational spillovers. All this suggests that the appropriate measure of growth is related to the growth in output of goods and services per worker and not to employment growth.

There is no direct evidence on whether output per worker increases faster in cities than in nonurban areas. But several recent studies have looked at differences in the growth of per capita income across the United States over the past six decades.[11] These studies found that while the level of per capita income differs across states, per capita income appears to grow at the same rate across states in the long run. These findings do not support the view that educational spillovers lead to permanently faster-than-average productivity and income growth in cities. Per capita income appears to be growing at the same rate in highly urbanized states (such as Massachusetts, where 96 percent of residents live in metropolitan areas) as in the least urbanized ones (such as Wyoming, which has only 15 percent of its population in metropolitan areas).

[11]See the studies by Gerald A. Carlino and Leonard Mills (1994) and Robert Barro and Xavier Sala-i-Martin (1992).

CONCLUSION

Because education generates spillovers, the additional social benefit of education exceeds the additional private benefit for any given individual. People will ignore these external benefits and, from society's point of view, underinvest in education. This underinvestment provides an important justification for public subsidies to education. Such subsidies encourage people to invest more in education, thereby enabling cities and the nation to reap the social benefits of additional education in terms of higher productivity.

But does investment in education and training lead to permanently faster growth in cities? The bulk of the evidence suggests that knowledge spillovers among workers do increase productivity in cities. But there is no evidence that knowledge spillovers lead to permanently faster-than-average population and employment growth in any given city. Nonetheless, the general concentration of people and firms in urban areas may facilitate the exchange of knowledge among workers and across firms that is so important for sustaining productivity growth in cities and the nation.

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