REVIEW

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Is Inflation Too Low?

William Poole

What is today's big monetary policy issue? It is, surely, the extraordinary volatility of the financial markets and the wide quality spreads that opened up between riskier bonds and Treasury bonds following the Russian default in mid-August 1998. No one forecast these problems; the financial-market upset certainly was not a real, live policy issue back in the spring and early summer.

We should not underestimate the magnitude of the current disturbance in the U.S. financial system. Monetary policy today is, I believe, appropriately focused on dealing with the possible effects of the financial-market disturbance on the U.S. economy. The size of that disturbance and the circumstances surrounding it are so unusual in the context of U.S. history that policymakers must concentrate on dealing with this situation for the time being.

The financial upset, however, will disappear from the radar screen of pressing policy issues as the markets settle down in due time. All of us will then return—or should return—to analyzing longer-run issues. With regard to the current outlook, I will say only that I am optimistic that we will work through current problems, painful as they have been for many, with no significant damage to the U.S. economy. My optimism stems from the economy's strong initial conditions of low inflation, low and stable inflation expectations, and a well-capitalized banking system. These are about as favorable a set of initial conditions as one can imagine for getting through financial turmoil with minimal effect on the real side of the economy.

The issue I wish to explore is this: Is zero inflation, abstracting from measurement error in the broad price indexes, too low? I think zero is a very nice number, especially when it comes to inflation. But there is a serious argument that the economy is likely to work better with a moderate inflation of, say, 2 or 3 percent per year. I disagree with that argument.

I will concentrate on two arguments for moderate inflation. The first argument holds that inflation facilitates the smooth operation of labor markets and thereby promotes maximum employment in the face of nominal wage rigidity. The second argument contends that inflation, via the Fisher relationship, keeps nominal interest rates from falling too close to the zero bound, and thereby gives the Fed sufficient room to ease—that is, to cut rates—should a recession appear imminent.

In my view, both arguments are wrong. I will begin by outlining some reasons why I believe that zero inflation should be the paramount objective of monetary policy.

THE CASE FOR ZERO INFLATION

As Chairman Alan Greenspan has pointed out on numerous occasions, our economy's fine performance since the early 1990s was accompanied initially by declining inflation and, more recently, by low and stable inflation. Clearly, the U.S. experience of the last five years casts doubt on the old claim that falling inflation will inevitably bring slower real growth or a higher rate of unemployment. This experience also suggests that reducing the variability of inflation need not increase the variability of output, as some people argue.

Although the performance of other countries with low inflation is somewhat mixed, my point is simply that there is little evidence to suggest that zero inflation necessarily implies slow real growth. Indeed, Robert Barro (1996) and others have reported systematic evidence to the contrary. Certainly, there are good reasons to expect that a zero-inflation monetary regime, sustained over the long run, would enhance an economy's performance.

If the monetary authority is committed credibly to zero inflation, then one source of interference with the efficient working of markets—uncertainty about expected inflation—would be reduced. Inflation uncertainty makes it difficult for individuals and firms to distinguish changes in relative prices among goods and services from movement in the aggregate price level. Mistakes in the allocation of resources are more likely to occur because of this uncertainty, with real growth consequently less than it could be.

By confusing the meaning of individual price changes, inflation uncertainty also raises uncertainty about the prospects of investment returns. A rising rate of inflation can lead both borrowers and lenders to be overly optimistic about likely returns, resulting in inefficient resource commitment. If the price expectations that are assumed when funds are committed are not realized, borrowers may encounter difficulty repaying their debts, which in turn puts stress on lenders. Thus, it is reasonable to expect that eliminating uncertainty about the rate of inflation will enhance, although obviously not guarantee, financial stability.

Presumably, to eliminate uncertainty, the rate of inflation need not be zero, but simply predictable. For at least two reasons, however, I believe zero should be the target. First, maintaining a steady but positive inflation rate probably would be harder politically than maintaining a steady zero inflation. The reason is that we live in a world where both politicians and economists often argue that just a little more inflation would generate positive real economic gains. If we accept the argument that 2 percent inflation is okay, why not 2.5 percent? Let me emphasize that when I advocate zero inflation, I am ignoring measurement questions, such as whether or not bias exists in the relevant price index. As a practical matter, policy is probably best specified in terms of a measured inflation range that accounts for our best estimate of measurement errors.

A second reason I advocate zero inflation concerns the distortions caused by the interaction of inflation with the tax code. Inflation indexing is incomplete, especially for investment income, because nominal interest income and nominal capital gains are subject to tax. Martin Feldstein (1997) has estimated that reducing inflation from its current level of about 2 percent to zero would yield substantial, permanent real income gains. Theoretical analysis by James Bullard and Steven Russell (1998), and others, also suggests that tax distortions cost the economy substantial real performance at higher rates of inflation.

In short, I think the case is strong that monetary policy should aim for zero inflation as its paramount objective. Moreover, I reject the approach that zero inflation must be shown to be superior to a poorly specified alternative of some positive inflation. The burden of proof really should fall on those who contend that positive inflation is better. So, let me now consider the arguments advanced for a positive rate of inflation.

LABOR MARKET ARGUMENTS

One perennial argument in favor of positive inflation is that certain wages must fall relative to other prices or other wages, and inflation allows this adjustment of real wages to occur in the face of nominal wage rigidity. The centerpiece of this argument is the claim that downward nominal wage adjustments occur too infrequently to be consistent with flexible real wages in a world where microeconomic shocks continuously alter the relative positions of particular firms, industries, or occupations. With zero inflation, the argument goes, rigid nominal wages prevent optimal adjustment to relative price disturbances with the result that employment varies inefficiently. Therefore, a little inflation is a good thing because it allows wages to fall relative to other prices; inflation "greases the wheels" of labor-market adjustment.

Zero Inflation in a Different Regime

There are, in my opinion, serious flaws at three levels of this argument. First, the argument claims that nominal rigidity creates a large inefficiency that inflation ameliorates. But, if the claim of a large inefficiency is true (and I will question it later), a simple theoretical argument creates the presumption that nominal wages would not continue to be sticky in a zero-inflation regime.

There is some dispute about the extent to which nominal wages are downwardly rigid. But, no doubt some employers have found it difficult to reduce nominal wages during the periods covered by the most popular data sources. One data source, the Panel Study of Income Dynamics, started during the late 1960s. I mention the sample period because making an empirical regularity the foundation, rather than an implication, of economic theory always is dangerous. Robert Lucas (1976) elegantly demonstrated this point more than 20 years ago. To the extent that downward nominal wage rigidity exists, it presumably serves some economic function. After all, putting minimum wage laws aside, fixed nominal wages are not required by law. We cannot assume that the present degree of wage rigidity—whatever it is—would continue into a different inflation regime. Indeed, a compelling case can be made that the extent of wage rigidity we observe would not survive in a zero-inflation regime.

Consider an environment where, broadly speaking, the annual changes in broad price indexes usually are close to zero and have been for some time. Suppose, also, that the Fed's commitment to maintaining this regime is clear. In such an environment, nominal wage rigidity, according to the grease-the-wheels argument, would generate a large inefficiency that inflation—now zero—would no longer ameliorate. This inefficiency, however, is exactly what should make us doubt that nominal wage rigidity would continue to exist. The main function of the price system is to allocate resources by setting relative prices. Competitive forces likely would eliminate anything that interferes with relative price adjustment, particularly if failure to adjust is very costly, unless there is some compelling reason for it to exist. Could we imagine that nominal wage rigidity would continue during a sustained 10 percent deflation? Of course not. Why? The private costs of interfering with relative price adjustment would be too high. It may take longer for competitive forces to erode nominal rigidity under zero inflation, but the principle is the same.

Keep in mind that the magnitude of ongoing resource reallocation in U.S. labor markets dwarfs the employment growth that makes headlines on the first Friday of every month. Jobs appear, jobs disappear, and people move into and out of them at rates far higher than net employment growth. This is *prima facie* evidence that U.S. labor markets do not suffer from any massive inefficiency.

If nominal wage rigidity creates significant economic inefficiency, it seems entirely plausible that it is perpetuated by inflation. I admit I do not know for sure. Based on the current state of economic theory, however, I think we must favor the presumption that inefficient wage rigidity would disappear in a zero-inflation economy. This position makes sense if we take economic theory seriously.

Other Mechanisms for Relative Wage Adjustment

A second flaw in the grease-the-wheels argument is that it imagines only two mechanisms for achieving adjustments to a worker's relative wage: Either cut the nominal wage, or let all other prices around it rise. In fact, the workings of labor markets suggest at least two other mechanisms, and so the presence of nominal wage rigidity—were it to exist—might not be a hindrance in a zero-inflation world.

First, average compensation tends to rise over time, as overall productivity improves. Thus, in a zero-inflation environment, nominal wages may not need to fall, even in some declining occupations. Proponents of the grease-the-wheels view sometimes ignore this mechanism.

Internal labor markets provide yet another adjustment mechanism. Compensation tends to increase with seniority, partly because of an individual's accumulation of human capital. Edward Lazear (1981) has argued that an upward-sloping path for earnings also acts as a mechanism to overcome agency problems within the firm. James Malcomson (1984) and others have argued that promotions may play a similar role; rather than simply filling positions necessary for the technological operation of the firm, promotions provide necessary incentives for those at lower levels of the hierarchy.

The common theme in these observations about internal labor markets is that an individual worker typically will expect an increasing real wage. Therefore, the kind of base adjustment achieved by inflation can also be accomplished by delaying wage change relative to an individual's upward-sloping real wage path.

Of course, there is a segment of the labor market where little human capital accumulation exists and long-term implicit contracts are rare. But, for obvious reasons, this is exactly the segment where turnover costs are low on both the supply and demand sides of the market. Hence, any nominal wage rigidity that is present is not especially costly.

INFLATION AND RELATIVE PRICE VARIABILITY ARE LINKED

The third flaw in the labor-market case for positive inflation is perhaps the most transparent. Inflation tends to increase the sort of microeconomic shocks—because cross-sectional variation in price changes tends to rise with higher aggregate inflation—that underlay the case for pursuing a positive rate of inflation. Thus, the claim that inflation helps the economy cope efficiently with relative price changes is suspect immediately, since there is more relative price variation to cope with if there is more inflation.

Labor Market Costs as Well as Benefits

Overall, I believe that the benefits of inflation as labor-market grease are exaggerated. Furthermore, inflation itself seems to worsen the problem it ostensibly alleviates. In addition to these theoretical arguments, we now have some direct evidence, supplied by Erica Groshen and Mark Schweitzer (1996, 1999). They recognize that compensation typically is set for at least a year, and that there are, in essence, two pieces to a firm's wage-setting process. First, management decides on the overall change in the wage pool, based in part on the rate of inflation expected to prevail during the following year. This wage pool, in effect, sets the firm-wide budget constraint. Second, individual wages and salaries are adjusted in a way that satisfies the budget constraint. This two-step process is explicit in many organizations.

Mistakes occur during the first stage when managers misforecast inflation. "Sand-in-the-wheels" effects occur if higher average levels of inflation result in more inflation variability, causing larger inflation forecasting errors. A consequence is that inflation will cause more interfirm variation in wage adjustment. Grease effects operate, as I outlined earlier, and imply more dispersion of interoccupational wage adjustment. The grease effects should taper off as inflation rises because some level of inflation enables employers to make all of the relative wage adjustments they would make in a frictionless labor market. Because they view wage setting as a two-stage process, Groshen and Schweitzer estimate the grease and sand effects separately. They find evidence of both effects, with sand effects rising rapidly with the inflation rate. Comparing the grease and sand effects directly, Groshen and Schweitzer find that even for low inflation rates the net benefit of inflation is statistically indistinguishable from zero, although point estimates of the gross benefit do slightly exceed estimates of gross cost.

One might quibble with the specifics of their empirical strategy, but Groshen and Schweitzer's emphasis on evaluating costs as well as benefits is absolutely correct. From the standpoint of labor markets, I think it is fair to say that the evidence of net benefits from an inflationary monetary policy is slim to none.

THE ZERO NOMINAL INTEREST RATE BOUNDARY

Now let us consider whether concerns about conducting countercyclical monetary policy in a low-inflation environment can justify a positive rate of inflation. Specifically, does price level stability cause special problems for monetary policy because nominal interest rates cannot be less than zero?

The zero-bound view is an old and much debated one in macroeconomics. With rising inflation during the 1970s and early 1980s, the issue largely became moot, as policymakers scrambled to get inflation back under control and to regain lost credibility. Recently, however, the topic has resurfaced as inflation rates in the industrialized countries have fallen and stayed low during the 1990s, and as central banks around the world have adopted inflation targeting as a method of achieving and committing to price stability.

The zero-bound view holds that moderate inflation aids in the implementation of stabilization policy by keeping nominal interest rates from falling too low. The bottom line, according to this argument, is that an inflation target of zero interferes with the attempts of monetary policymakers to stimulate an economy in recession because the nominal interest rate obviously cannot fall below zero. Put another way, with moderate ongoing inflation the policymakers have room to push the real rate of interest below zero, which they cannot do when the steady inflation rate is zero.

The zero-bound story begins with the commonplace idea that monetary policy is concerned with setting a short-term nominal interest rate—in the United States, the nominal federal funds rate. A higher nominal federal funds rate is often described as a tighter policy, while a lower nominal federal funds rate is described as an easier policy. When the economy is weak, the monetary authorities lower the nominal federal funds target in an effort to stimulate interest-rate-sensitive sectors of the economy. So according to this view, when a recession hits, the current level of the federal funds rate determines the number of basis points the Fed has available to combat the recession: the lower the initial funds rate, the less scope for subsequent easing. As you might guess, I dislike this characterization of monetary policy, but let me finish the story.

Of course, financial market participants are interested mainly in the real interest rate, not the nominal interest rate. A simple Fisherian decomposition divides any nominal interest rate (with zero default risk) into two major components—a real component determined by equilibrium conditions in the economy and a nominal component determined by the expected inflation rate.

The zero-bound view holds that the expected inflation component of nominal interest rates moves little over periods as long as a year, so that adjustments in the nominal federal funds rate mainly change real returns at the very short end of the term structure. Movements in short-term rates then lead to adjustments in longer-term real interest rates.

What hampers stabilization policy in a low-inflation environment, according to the zero-bound view? If inflation is zero and expected to remain that way, then the expected inflation component of nominal interest rates is zero, and the nominal rate is lower on average than it would be in a world of persistent inflation. Thus, in a recession, the Fed would have less room to cut interest rates because of the zero nominal bound. The end result, according to this view, is a longer and deeper recession than would otherwise be the case. The message is clear: If the Fed is to help the economy in times of distress, nominal interest rates must be kept high enough in normal times, which requires maintaining a modest rate of inflation.

The zero-bound view has raised many counterarguments over the years. Perhaps most obviously, this view places heavy emphasis on the idea that monetary policy can be used to fine tune the macroeconomy, downplaying well-known concerns that attempts to fine tune can contribute to economic instability. Leaving that issue aside, however, there are still several reasons to doubt the validity of the zero-bound argument for pursuing a policy of positive inflation.

Monetary Policy Is Fundamentally Not About Nominal Interest Rates

First, we must remember that nominal interest rates do not indicate the true stance of monetary policy even though, as a practical matter, the Fed implements short-term policy by targeting the nominal federal funds rate. This method of implementation has been effective in recent years. Controlling the funds rate is not, however, an end in itself. Fundamentally, monetary policy is reflected in the growth of the money stock and, ultimately, the rate of inflation. So the idea that central bankers are somehow trapped if the nominal short-term interest rate nears zero seems quite a stretch to me. We are in the business of providing liquidity to the macroeconomy, and if the situation calls for it, liquidity can always be injected, regardless of the level of nominal interest rates.

The first years of the Great Depression offer perhaps the clearest illustration that monetary policy is fundamentally about providing liquidity and not about controlling nominal interest rates. During that time, nominal interest rates were low, which seemed to indicate an "easy" monetary policy. But as Milton Friedman and Anna Schwartz (1963) have noted, from 1930 to 1933 the money stock was falling rapidly, indicating a far tighter policy than was intended. Of course, that policy was an unmitigated disaster, as both output and prices fell by a third and the unemployment rate hit 25 percent. That experience, as well as other, less dramatic historical episodes, should make it obvious that blind adherence to nominal interest rates as indicators of the stance of monetary policy can be tragically misleading.

We might also do well to remember that during the late 1950s and early 1960s, the nominal annualized yield on three-month Treasury bills fluctuated around 3 percent, while the yield on 10-year Treasury bonds was around 4 percent. These yields are below, but in the general ballpark, of those we observe today. Consumer price index inflation during that period averaged about 2 percent on a year-over-year basis—not too different from today's inflation rate. So, while we have not seen a sustained zero-inflation environment in the United States during the postwar era, we have seen an environment not too different from today's in terms of relatively low inflation. And during the late 1950s and early 1960s, there was no obvious impediment to the operation of monetary policy just because inflation was low.

Inflation and Output Variability

The relative stability of our economy in recent years suggests that low inflation probably contributes both to less inflation variability and to less output variability. Throughout the 1970s and early 1980s, by contrast, when inflation rose sharply and then fell abruptly, the United States suffered through three recessions, including two of the most severe recessions of the postwar era. To be sure, during that period, the U.S. economy was hit with shocks from external sources, but at the same time monetary policy was decidedly uneven—resulting in a substantial inflation that caused both unnecessary distortions and proved difficult to tame. Thus, the postwar experience strongly suggests that lower inflation is associated with less volatile inflation, and lower inflation volatility is reflected in lower volatility in real output. Even in a zero-inflation environment the lower bound on nominal interest rates probably would not be a problem for stabilization policy because economic volatility itself would likely be lower.

Nonlinear Effects Near Zero

A final reason to doubt that monetary policy would run aground in a zero-inflation world stems from the nonlinearity of investment demand. This nonlinearity implies that a given interest rate change, measured in basis points, may well have a larger impact when interest rates are low than when they are high.

Much of the thinking behind the zero-bound view is centered on the extrapolation of linear effects to very low interest rate environments. In much of the work on this issue, the average effects of short-run monetary policy changes are estimated using postwar data, which include many years of high inflation. There is little reason to think that coefficients estimated from an environment of relatively high inflation would be good proxies for the coefficients in the new circumstance.

We might expect that a given basis points change in the nominal federal funds rate target would have a larger impact when interest rates are lower. Certainly, there is no reason to expect that the response of investment to changes in the nominal interest rate is linear. At any point in time countless investment projects are available, and as the nominal cost of funds moves lower, the net present value of many more of these projects becomes positive. Accordingly, investment would be unbounded at very low real interest rates, implying that the Fed could conduct a countercyclical policy just as actively and effectively when interest rates were low, even if the nominal federal funds rate target was near zero.

ZERO INFLATION IS NOT TOO LOW

To summarize, it seems to me that neither the arguments about wage stickiness nor those concerning the zero bound for nominal interest rates make a convincing case that monetary policy should aim for a positive rate of inflation. Instead, I believe the logic and the evidence both suggest that the appropriate goal for monetary policy should be price stability, that is, a long-run inflation rate of approximately zero.

Today we are enjoying the benefits of a low and comparatively stable rate of inflation. In our present state, we should not forget the high costs of inflation. Inflation makes planning difficult for individuals and firms, it interferes with the operation of markets, and it interacts insidiously with the tax code to discourage saving and investment. Moreover, inflation's effects are felt most acutely by members of society who are economically the most vulnerable. In arguing for a positive rate of inflation, therefore, the burden of proof should rest with those who contend that our economy would perform better with inflation than without it. Inflation proponents also should explain how a moderate rate of inflation could be maintained without inching ever higher. In my view, the case for positive inflation has not been proven.

A central bank's single most important job is preserving the value of the nation's money. Monetary policy has succeeded if the public can reasonably trust that a dollar will buy tomorrow what it will buy today. At this point, inflation will have ceased to be a hindrance to the smooth functioning of our market economy. I cannot promise that price stability will mean an end to the business cycle, to unemployment, or to occasional financial distress. Indeed, I am willing to bet that a few years from now we will look back on 1998 and conclude that the stability of the inflation environment was important to containing the financial-market upset that started in August.

We should not be seduced by arguments that a little inflation is a good thing. Look at the record: Over the past 50 years, our economy has performed better when inflation was low than when it was high. There simply is no compelling evidence that we could foster sustained economic growth by pursuing an inflationary monetary policy. The evidence points in the other direction. Thus, I am confident that our economy's long-run performance would be enhanced by a monetary policy that aims at, achieves, and maintains a zero rate of inflation.

REFERENCES

Barro, Robert J. "Inflation and Growth," this *Review* (May/June 1996), pp. 153-69.

Bullard, James B., and Steven H. Russell. "How Costly Is Sustained Low Inflation for the U.S. Economy?" Federal Reserve Bank of St. Louis Working Paper 97-012B, March 1998.

Feldstein, Martin. "Capital Income Taxes and the Benefits of Price Stability," NBER Working Paper 6200, September 1997.

Friedman, Milton, and Anna Jacobson Schwartz. *A Monetary History of the United States, 1867-1960*, Princeton University Press, 1963.

Groshen, Erica L., and Mark E. Schweitzer. "The Effects of Inflation on Wage Adjustments in Firm-Level Data: Grease or Sand?" Federal Reserve Bank of New York Staff Report No. 9, January 1996.

__________ and __________. "Identifying Inflation's Grease and Sand Effects in the Labor Market," in *The Costs and Benefits of Price Stability*, Martin Feldstein, ed., University of Chicago Press, 1999, pp. 273-308.

Lazear, Edward P. "Agency, Earnings Profiles, Productivity, and Hours Restrictions," *American Economic Review* (September 1981), pp. 606-20.

Lucas, Robert E., Jr. "Econometric Policy Evaluation: A Critique," in *The Phillips Curve and Labor Markets*, Karl Brunner and Allan H. Meltzer, eds., Carnegie-Rochester Conference Series on Public Policy, North Holland, 1976, pp. 19-46.

Malcomson, James M. "Work Incentives, Hierarchy, and Internal Labor Markets," *Journal of Political Economy* (June 1984), pp. 486-507.

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The FOMC in 1998: Can It Get any Better Than This?

David C. Wheelock

The U.S. economic expansion barreled into its eighth consecutive year during 1998, the longest peacetime expansion since World War II. Amidst rapid growth, inflation remained low, the unemployment rate declined to its lowest point since 1970 and real earnings rose at their fastest rate since 1972. The stock market, like the economy, continued to soar and the Federal Government budget was in surplus for the first time since 1969. The year was not unblemished, however, as recession and financial instability in Asia, Russia, and parts of Latin America roiled international financial markets during the second half of 1998. Slow growth abroad also substantially weakened the foreign demand for U.S. products and, despite a large increase in exports during the fourth quarter, the U.S. trade deficit widened to a record for the year as a whole.

This article reviews Federal Reserve monetary policy actions and concerns during 1998. From the standpoint of monetary policy, the year's pivotal point occurred in August, when the Russian government defaulted on its domestic debt and devalued the ruble. Before August, policymakers focused on whether an explicit policy tightening would be needed to slow domestic demand enough to prevent an increase in inflation. Although inflation currently was low, extraordinarily tight labor markets, rapid growth of monetary aggregates, and strong consumer spending all seemed to point toward higher inflation to come. Accordingly, at their meetings from March to July, Federal Open Market Committee (FOMC) members voted to bias their policy instructions toward a tighter policy, in effect signaling that their next explicit action would likely be a tightening move. Two committee members dissented on at least one occasion in favor of an immediate tightening.

Financial market upset triggered by the Russian government's default and devaluation of the ruble, coupled with ongoing concern about economic weakness in Asia and Latin America, caused a reevaluation of the risks to the U.S. economy during the second half of 1998. As Federal Reserve Chairman Alan Greenspan remarked before Congress on September 23, the United States cannot "remain an oasis of prosperity unaffected by a world that is experiencing greatly increased stress" (Testimony before the Committee on the Budget, U.S. Senate, "The Crisis in Emerging Market Economies," September 23, 1998). Between September and November, the Federal Reserve eased monetary policy in three successive steps to "cushion the effects on prospective economic growth in the United States of increasing weakness in foreign economies and of less accommodative financial conditions domestically" (FOMC Press Release, September 29, 1998).

This article begins by reviewing key macroeconomic outcomes for 1998. Next, the article describes the FOMC's focus on domestic spending growth, tight labor markets, and surging money stock growth as signals of a possible increase in the rate of inflation. Finally, the article turns to a review of the discussion and decisions taken at each FOMC meeting during 1998. This section highlights, in particular, the actions taken by the FOMC during September-November to accommodate increased demand for liquidity in financial markets following the Russian government's default and devaluation of the ruble, worsening economic conditions in Asia and

Figure 1

Core CPI Inflation and Real GDP Growth

Q4 over Q4

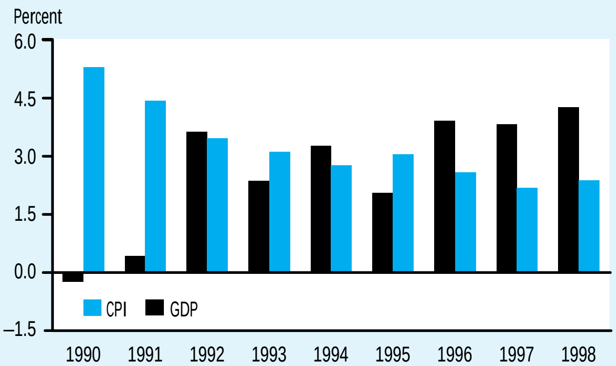
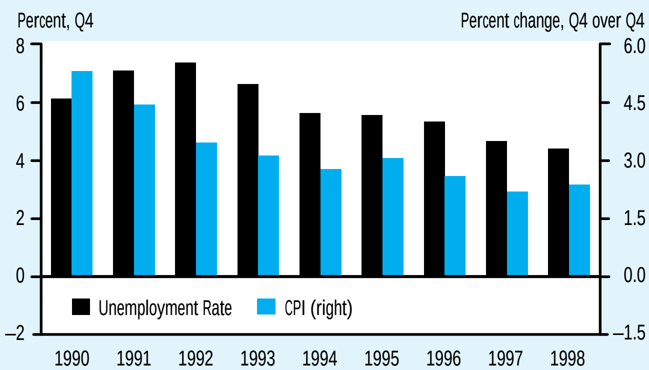


Figure 2

Core CPI Inflation and Unemployment Rate



parts of Latin America, and attendant global financial instability.

1998: A REVIEW OF THE NUMBERS

1998 was a remarkably good year from the perspective of most macroeconomic indicators. After seven continuous years of expansion, and in the face of faltering economic performance in Japan and other key trading partners, logic seemed to suggest that the pace of U.S. output growth had to slow. But, it did not. At 3.9 percent, real GDP growth in 1998 equaled its pace of 1997, which itself was a year when growth was well above its historical average rate.

During 1997, FOMC officials, like most private sector forecasters, were surprised by the economy's ability to achieve rapid growth without an increase in inflation (see Yoo, 1998). With the economy thought to be at full employment, and with ample liquidity in credit markets and rapid growth of monetary aggregates, most forecasters again predicted higher inflation during 1998. But, inflation did not rise. Instead the GDP deflator rose a mere 1.0 percent (against 1.9 percent in 1997), while the Consumer Price Index (CPI) increased just 1.6 percent (against 2.3 percent in 1997), its lowest rate since 1964.[1] The unemployment rate, moreover, also fell, dipping to as low as 4.3 percent in April and December, its lowest level since February 1972. Further reflecting strength in the labor market, real average hourly earnings rose 2.74 percent, their highest increase since 1972.

Figures 1 and 2 illustrate the exemplary performance of the U.S. economy since the recession of 1990-91. The recovery from this recession has been unusual. Typically, real GDP grows rapidly during the initial recovery period, and slows to trend growth as the expansion matures. In the present recovery, however, growth was slow initially, but has since accelerated. Inflation, by contrast, has fallen with higher real GDP growth and decline of the unemployment rate. The favorable, but somewhat unusual, behavior of the economy during recent years has posed a challenge for macroeconomic policymakers—namely, to understand why the economy has performed so well and to implement policies that will best ensure continued favorable performance.

Monetary Policy Before August: Where's the Slowdown? Where's the Inflation?

As 1998 began, analysts were puzzled by the fact that the Asian recession had not yet had any serious impact on the U.S. economy. Exports had declined, causing distress among some producers dependent

[1] Adjustments in the measurement of the CPI by the Bureau of Labor Statistics during 1998 accounted for 0.21 percentage points of the decline in CPI inflation between 1997 and 1998. That is, CPI inflation would have been 0.21 percentage points higher during 1998 had these adjustments not been made. See *Economic Report of the President* (1999, p. 94).

on foreign markets, but strong domestic demand pushed the U.S. economy forward at a rapid pace. As unemployment dipped further with no signs of slower economic growth, many forecasters questioned whether inflation could remain low. Economists who thought that NAIRU—the acronym for "non-accelerating inflation rate of unemployment"—was approximately 5 percent of the labor force, became increasingly concerned about higher inflation as the unemployment rate dropped further below this level. Federal Reserve governor Laurence Meyer, for example, noted that his "best guess" estimate of NAIRU was 5 1/2 percent, and though "special forces," such as unusual declines in commodity and import prices, had held inflation temporarily in check, "the very tight labor markets can be expected to put upward pressure on wage change and hence inflation" ("The Economic Outlook and the Challenges Facing Monetary Policy," Public Policy Meeting, Federal Reserve Bank of Atlanta, April 9, 1998).

Throughout the first half of 1998, the FOMC frequently discussed the question of whether "tight labor markets" and accelerating increases in labor compensation signaled a forthcoming increase in inflation. For example, at the meeting of May 19, the committee concluded that "The decline in the unemployment rate to its lowest level in nearly three decades underscored anecdotal reports of further tightening in labor markets in recent months and added to concerns about the outlook for inflation." At the same time, committee "members acknowledged, however, that the nexus between labor market tightness, accelerating labor costs, and the effects on price inflation was very difficult to ascertain and analyses based on earlier patterns that pointed to rising inflation had proved consistently wrong in recent years."[2]

Rapid and accelerating growth of monetary aggregates was a second source of concern about inflation discussed at FOMC meetings during 1998. Although the FOMC had established an annual growth rate target for M2 of 1-5 percent,

Table 1

Annual Percentage Growth Rates of M2 and MZM
(Seasonally Adjusted)

	M2	MZM
1997:1	4.86%	7.28%
1997:2	4.83	6.68
1997:3	6.49	9.23
1997:4	6.84	9.91
1998:1	7.79	11.49
1998:2	7.70	13.64
1998:3	7.04	12.17
1998:4	11.45	19.38

M2 is the sum of currency held by the public, demand, and other checkable deposits issued by financial institutions (except those issued to the U.S. Treasury or depository institutions), travelers checks, small savings, and time deposits issued by financial institutions, and shares in retail money market mutual funds (excluding retirement accounts). MZM, i.e., "money, zero maturity," equals M2 plus institutional money market fund shares, minus small time deposits. Finally, M3 consists of M2 plus large time deposits, repurchase agreements issued by depository institutions, Eurodollar deposits, and institutional money market fund shares. The Federal Reserve sets growth targets for M2 and M3, but not for MZM. MZM, however, is frequently used for analytical purposes. Additional detail can be found in the *Federal Reserve Bulletin*, or *Monetary Trends*, a monthly publication of the Federal Reserve Bank of St. Louis.

M2 growth exceeded 6 percent during the second half of 1997, and 7 percent during the first half of 1998. At the same time, growth of money, zero maturity (MZM), which is not targeted by the FOMC, exceeded 9 percent, rising to over 11 percent in early 1998 (see Table 1).

The FOMC sets target ranges for money stock growth. They should be viewed as benchmarks for money growth that would be associated with price stability and sustained economic expansion, assuming velocity will behave consistently with historical patterns. The FOMC has tended to downplay the usefulness of the aggregates as policy guides in recent years because velocity has behaved erratically in the past.[3] Nevertheless, accelerating growth of the monetary aggregates, in conjunction with other evidence that aggregate demand was increasing at an inflationary pace, caused two

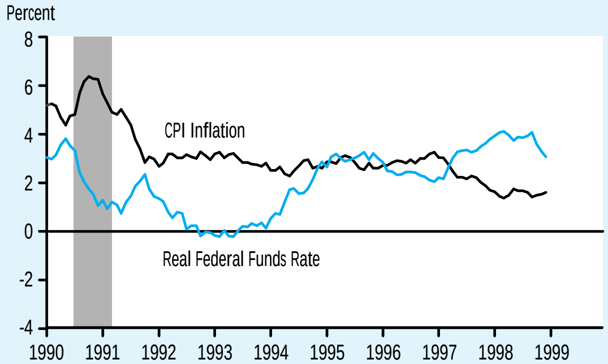
[2] The minutes of each FOMC meeting are published soon after the committee's next regularly scheduled meeting, and are available from the Board of Governors web site and in the *Federal Reserve Bulletin*.

[3] For evidence that the velocity of M2 recently has behaved more consistently with its historical pattern, see Anderson (May 1997) or Dewald (October 1998).

Figure 3

Real Federal Funds Rate and Inflation

Monthly data, 1990-1998



FOMC members to dissent at least once in favor of moving immediately to a tighter policy stance. A majority of the FOMC, while not persuaded that rapid money stock growth alone justified a tighter monetary policy, viewed labor market tightness, rapid money growth, and perhaps other factors, as increasing the likelihood that a tighter policy would be necessary over the near term. Accordingly, at its meetings from March to July, the FOMC voted to tilt its policy directive toward a tighter policy. In introducing this asymmetry into its policy instructions, the committee refrained from an immediate, overt tightening of policy, but signaled its expectation that an actual tightening would most likely be the committee's next move.

Although the FOMC did not overtly tighten policy during 1998, by leaving its federal funds rate target unchanged, the "real" federal funds rate (measured as the difference between the nominal funds rate and the current CPI inflation rate) was permitted to rise as inflation fell. As Figure 3 illustrates, this continued a pattern that began during 1997.[4] By this measure, monetary policy had tightened during the period, even though the Fed had not taken an explicit action. This passive tightening was not inadvertent, according to Chairman Greenspan: "The FOMC … allowed the real funds rate to rise with continuing declines in inflation and, presumably, inflation expectations" (Testimony before the Committee on Banking, Housing, and Urban Affairs, U.S. Senate, February 23, 1999). The objective of this passive tightening of policy was to discourage an increase in inflation that might threaten continued economic expansion. As noted, however, labor markets remained tight and money growth rapid, which during the first half of 1998 left policymakers concerned that passive tightening would not prevent an increase in inflation.

Exceptional growth of output and employment, without an increase of inflation, defied conventional economic rules-of-thumb during 1998. The year proved, once again, the folly of relying solely on the stability of either output (or employment) gap or monetary aggregate growth rate relationships with near-term inflation. Economists are aware that such relationships can break down for a variety of reasons. Since the early 1980s, for example, financial innovations have rendered unstable the relationship between short-run changes in narrow monetary aggregates, such as M1, and inflation. During 1998, unusual gains in productivity appear to explain how output growth could rise as fast as it did, and the unemployment rate fall as much as it did, without an increase in the rate of inflation.

In congressional testimony, Federal Reserve Chairman Alan Greenspan argued that the United States has enjoyed a "virtuous cycle" of investment-driven productivity gains stimulated by low inflation and optimistic expectations about future economic growth. Productivity growth then, in turn, has fueled expectations of future economic returns, prompting further investment, and so forth:

> Evidence of accelerated productivity has been bolstering expectations of future corporate earnings, thereby fueling still further increases in equity values, and the improvements in productivity have been helping to reduce inflation. In the context of subdued price increases and generally supportive credit conditions, rising equity values have provided impetus to spending

[4] The FOMC increased its funds rate target by 25 basis points to $5\frac{1}{2}$ percent on March 25, 1997. This was the committee's only explicit policy change during that year.

and, in turn, the expansion of output, employment, and productivity-enhancing capital investment. (Testimony before the Committee on Banking, Housing and Urban Affairs, U.S. Senate, July 21, 1998)

Figures 4 and 5 provide two measures of productivity growth—nonfarm business productivity growth and manufacturing productivity growth. Typically, productivity growth declines, and may turn negative, as the economy enters a recession. Productivity growth then increases sharply late during the recession and initial recovery phase. Although volatile, productivity growth often falls as the expansion matures.

As is typical, productivity growth surged during the initial year of recovery from the 1990-91 recession. After little growth in 1993-95, however, productivity increased sharply beginning in 1996 and could, in principle, explain the simultaneous increase in real earnings and output growth and the decline in inflation. Indeed, the recent surge raises the question of whether the long-run, or trend, rate of productivity growth has increased. If it has, then the economy's long-run potential growth rate is higher than the approximately 2½ percent pace that economists thought possible. And, the "natural" rate of unemployment may now be closer to the 4-4½ percent rate of the 1960s than to 5½-6 percent, the rate economists widely believe prevailed during the 1980s. A number of model-based estimates of the natural rate of unemployment, however, currently remain in the 5¼-5½ percent range.

Forecasting changes in the trend growth of productivity, or even measuring the true level of productivity at any point in time, is notoriously difficult (see, e.g., Griliches 1994). Unfortunately, mismeasuring productivity trends, and hence, potential output growth, can have serious implications for monetary policy. For example, suppose policymakers follow a rule of easing policy whenever the observed rate of GDP growth falls below its assumed potential rate. Then, suppose that an unexpected decline in productivity growth causes both actual and potential GDP growth to fall simultaneously and proportionately, so that the output gap has not changed. Unless policymakers understand immediately that potential growth has fallen, and revise their assumptions accordingly, they will ease monetary policy. Such an action could prove destabilizing, however, causing a higher rate of inflation for a given rate of GDP growth, than would occur if no action were taken.

During 1998, Fed officials faced similar uncertainty about potential output. If the combination of rapid output growth and low inflation reflected a permanent increase in the rate of productivity growth, a tighter monetary policy might cause output growth to fall temporarily below

Figure 4

Nonfarm Business Productivity Growth

Quarterly data, 1960-1998

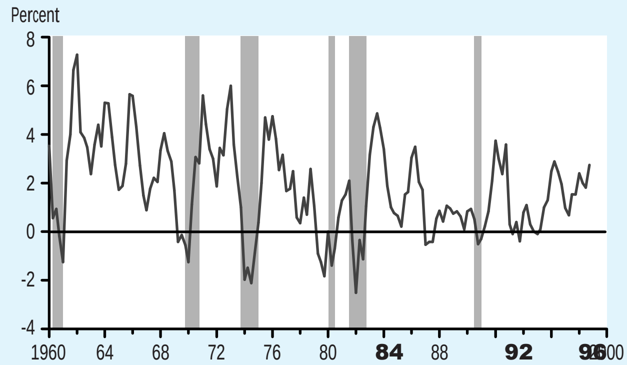
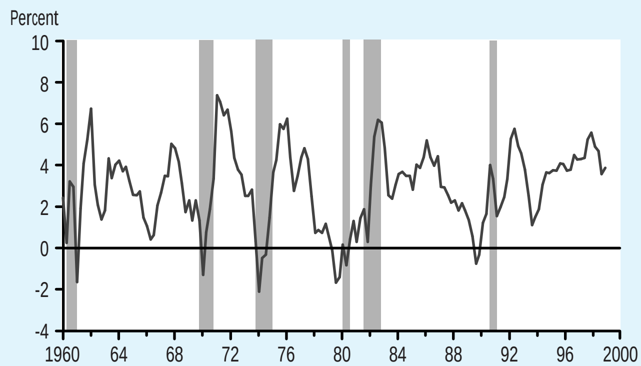


Figure 5

Manufacturing Productivity Growth

Quarterly data, 1960-1998



its potential, and possibly put downward pressure on the price level. On the other hand, if recent gains in productivity are only temporary, failure to tighten monetary policy when the economy is growing at such a rapid pace could result in an eventual increase in inflation. Indeed, an increase in inflation could erode productivity growth, possibly resulting in lower potential output growth over time.[5]

Because higher inflation might discourage productivity-enhancing investment and lessen the economy's growth potential, price stability has become an increasingly important objective of monetary authorities in many countries. Several countries, as well as the European Monetary Union, have made price stability the sole objective of monetary policy. This emphasis reflects, at least in part, the now widely held view that a credible commitment to preserving price stability best promotes maximum economic growth over the long term. Chairman Greenspan argues that the "virtuous cycle" that has propelled the strong U.S. economy was an outcome of reducing inflation to near zero:

> The essential precondition for the emergence, and persistence, of [the] virtuous cycle is arguably the decline in the rate of inflation to near price stability. … Risk premiums and economic disincentives to invest in productive capital diminish as the economy approaches price stability. … Technological innovations and the rapidly declining cost of capital equipment that embodies them in turn seem to be a major factor behind the recent enlarged gains in productivity. (Testimony before the Committee on Banking, Housing, and Urban Affairs, U.S. Senate, July 21, 1998)

The possibility that inflation might, in fact, hamper growth, explains why preserving price stability has become the paramount objective of monetary policy in central banks throughout the world.[6] And, it was a concern that a reemergence of inflation might endanger the ongoing economic expansion that proved to be the central focus of FOMC policy deliberations during the first seven months of 1998.

Table 2 summarizes the FOMC's decisions during 1998, as reflected in the policy directives issued by the FOMC to the open market trading desk. It also lists the voting members of the committee.[7] A review of the issues that seemed to weigh heavily in the discussion at each meeting during the first half of 1998 follows.[8]

February 3-4. At the first FOMC meeting of the year, the committee discussed current economic data and the staff forecast for the year ahead. The staff predicted that the economic expansion would "slow appreciably" over the next several quarters, primarily because slower growth abroad and appreciation of the dollar would substantially reduce the demand for U.S. exports. Despite slower output growth, however, inflation was forecast to increase somewhat as declines in energy and import prices were expected to abate.

The FOMC members agreed that the economy was likely to slow during 1998, with a prospective decline in exports and moderation in the growth of business inventories cited as the principal causes. The committee concluded, however, that the "risks of a considerable deviation on the upside or the downside of their current forecasts were unusually high," and that "the potential extent of the negative effects of developments in Asia on the nation's trade balance represented key uncertainty in the economic outlook."

The FOMC members also expressed uncertainty regarding the present stance of monetary policy. They noted that the real federal funds rate was unusually high, but that "financial conditions seemed to be quite stimulative as evidenced by lower nominal and perhaps real intermediate and long-term interest rates, rising equity prices, ready credit availability, and rapid growth of the broad measures of money and credit." In the face of these uncertainties, the FOMC decided unanimously to leave the current stance of policy unchanged by retaining its current target for the federal funds rate of 5½ percent.

[5] See Orphanides (1998) for a formal analysis of the effects of measurement uncertainty on optimal monetary policy.

[6] Although theoretically appealing, an empirical relationship, either positive or negative, between inflation and long-run real economic growth has been found to depend on the choice of countries studied as well as the time period and estimation method. See Barro (1996) and Bruno and Easterly (1996) for two recent empirical studies of this relationship.

[7] The FOMC consists of the seven members of the Board of Governors of the Federal Reserve System and the presidents of the 12 Federal Reserve Banks. Only five Reserve Bank presidents are voting members of the committee, however. The president of the Federal Reserve Bank of New York is always a voting member, and serves as the committee's vice chair, while the remaining Reserve Bank votes are rotated among the other 11 Reserve Bank presidents.

[8] All quotations in this section are from the minutes of the various FOMC meetings.

Table 2

Summary of FOMC Decisions in 1998

Meeting Date	Federal Funds Rate Target	Intermeeting Stance	Dissents
February 3-4	5.50	symmetric	none
March 31	5.50	asymmetric (tighter)	Jordan
May 19	5.50	asymmetric (tighter)	Jordan, Poole
June 30-July 1	5.50	asymmetric (tighter)	Jordan
August 18	5.50	symmetric	Jordan
September 29	5.25	asymmetric (easier)	none
October 15*	5.00	not applicable	not applicable
November 17	4.75	symmetric	Jordan
December 22	4.75	symmetric	none

* October 15 was not a regularly scheduled meeting of the FOMC, but rather a conference call in which the members agreed that the federal funds rate target should be reduced by 25 basis points.

Members of the Federal Open Market Committee in 1998

Alan Greenspan, Chairman. Chairman of the Board of Governors of the Federal Reserve System
William J. McDonough, Vice Chairman. President of the Federal Reserve Bank of New York
Roger W. Ferguson, Jr. Governor of the Federal Reserve System
Edward M. Gramlich. Governor of the Federal Reserve System
Thomas M. Hoenig. President of the Federal Reserve Bank of Kansas City
Jerry L. Jordan. President of the Federal Reserve Bank of Cleveland
Edward W. Kelley, Jr. Governor of the Federal Reserve System
Laurence H. Meyer. Governor of the Federal Reserve System
Cathy E. Minehan. President of the Federal Reserve Bank of Boston
Susan M. Phillips.** Governor of the Federal Reserve System
William Poole.** President of the Federal Reserve Bank of St. Louis
Alice M. Rivlin. Vice Chairman of the Board of Governors of the Federal Reserve System

** Ms. Phillips resigned from the Board of Governors of the Federal Reserve System during 1998, and attended her last meeting on May 19. Mr. Poole was appointed President of the Federal Reserve Bank of St. Louis on March 23, and attended his first FOMC meeting on March 31. Robert D. McTeer, Jr., President of the Federal Reserve Bank of Dallas, voted as an alternate member of the FOMC at the meeting of February 3-4.

March 31. By the second meeting of 1998, a majority of the FOMC had become less optimistic about the outlook for inflation. Despite continued projections from the staff that the economic expansion would slow appreciably over the near term, FOMC members concluded that

> … domestic demand was exceeding expectations and was likely to continue to increase rapidly for some time, supported by accommodative conditions in key segments of financial markets. Developments in foreign trade were moderating demands on domestic resources; but with domestic spending strong, members were becoming more concerned that those developments might not exert enough restraint on aggregate demand to slow the expansion to a sustainable pace.

Consequently, "the members agreed that should the strength of the economic expansion and firming of labor markets persist, policy tightening likely would be needed at some point to head off imbalances that over time would undermine the expansion in economic activity." As a result, the committee voted to maintain the prevailing federal funds target of 5½ percent, but to adopt an asymmetrical directive tilted toward a tighter policy.

Jerry L. Jordan, President of the Federal Reserve Bank of Cleveland, dissented from the policy directive adopted at the March 31 meeting. In his view, prevailing rapid money stock growth was likely to reignite inflation and, thus, the FOMC should tighten policy immediately.

May 19. At the FOMC meeting of May 19, Jordan again dissented in favor of an immediate tightening of monetary policy. He was joined by William Poole, President of the Federal Reserve Bank of St. Louis. Both presidents felt that, unless checked, rapid money stock growth would bring about an increase in the rate of inflation and ultimately threaten the economic expansion.

A majority of the FOMC, however, concluded that the outlook for inflation and continued economic expansion was too uncertain to warrant an immediate change in monetary policy. The committee noted that the economy was continuing to grow more rapidly than had been forecast, or than was sustainable over the long run. Nevertheless, as the committee staff continued to predict, most FOMC members were persuaded that economic growth would moderate appreciably during the coming quarters. Moreover, there was concern that an explicit tightening of policy by the Fed "could have outsized effects on the already very sensitive financial markets in Asia," with the resulting "unsettlement" having "substantial adverse repercussions on U.S. financial markets and, over time, on the U.S. economy." In light of these concerns, the FOMC elected not to change the current stance of monetary policy. At the same time, the committee agreed to retain a bias in its operating directive towards a tighter policy, which reflected a consensus that the balance of risks indicated that the next explicit policy action would be a tightening move in order to ward off an increase in inflation.

June 30-July 1. Information available at the time of the FOMC meeting of June 30-July 1 suggested that the rapid pace of economic activity had slowed. A strike at General Motors was expected to substantially reduce the nation's industrial production during June. Preliminary indications were that business inventory accumulation also had fallen substantially during the second quarter, as did business fixed investment. The trade deficit also continued to increase, further suggesting that output growth had slowed during the second quarter. On the other hand, labor markets remained exceptionally tight, with substantial increases in employment outside of manufacturing. Retail sales also continued to increase strongly. In light of mixed signals from the nonfinancial side of the economy, and with monetary and credit aggregates continuing to grow strongly, the FOMC elected to continue to "wait and see" before making an explicit change in policy. The committee did, however, retain its bias towards a tighter policy and, once again, President Jordan dissented from the committee's decision in favor of an immediate tightening of policy.

RESPONDING TO FINANCIAL SHOCKS

August 18. "Wait and see" was again the outcome of FOMC deliberations on August 18. Further evidence of domestic slowing, coupled with further economic deterioration in Japan and other Asian countries, and a partial debt default and currency devaluation by Russia on August 17 received the committee's focus. Although consumer spending and nonmanufacturing job growth remained strong, retail sales and industrial production declined in July, even with adjustment for the effects of the General Motors strike.

Perhaps most alarming to the committee was the deterioration in foreign economies: "In Japan … economic activity appeared to have contracted sharply further during the second quarter. In most other Asian economies, currencies and equity prices were under downward pressure, and in Russia, asset values plummeted in often disorderly markets. Risk spreads on dollar-denominated debt widened substantially, not only in Russia but for Latin American issuers as well."

Regarding the near-term outlook for the domestic economy, FOMC members pointed out that "unusually favorable underlying factors, including solid ongoing gains in employment and incomes and substantial further increases in household net worth" suggested that domestic demand for goods and services was unlikely to moderate substantially anytime soon. Moreover, "business fixed investment also seemed to be on a solid upward trajectory" and construction activity remained high. On balance, a majority of the committee concluded that "Greater difficulties abroad and associated downward pressures on demand and prices had substantially diminished the chances of a strengthening of inflation pressures over coming months and quarters that would require a near-term tightening of policy." A minority, however, felt that the risks remained weighted toward an increase in inflation. Nevertheless, while not changing its target for the federal funds rate, the FOMC removed the bias in its directive towards a tighter policy. Once again, President Jordan dissented, "because he believed that the underlying strength of aggregate demand in the U.S. economy would remain fundamentally intact, despite economic problems abroad," and "continued rapid growth in the money supply creates the risk that inflation will accelerate."

September 29. Global financial markets became increasingly unsettled during September and early October, precipitating a "flight to quality" of funds from relatively high risk, illiquid securities toward less risky, more liquid instruments. Yields on U.S. Treasury securities plunged, while those on high-quality corporate offerings declined less, and those on some low-quality securities rose. Figure 6 illustrates this phenomenon, showing the increases in average yields on Aaa and Baa-rated corporate bonds relative to the yield on 10-year U.S. Treasury securities, and the increased

Figure 6

U.S. Bond Market Quality Spreads

Daily data, January 1998 to January 1999

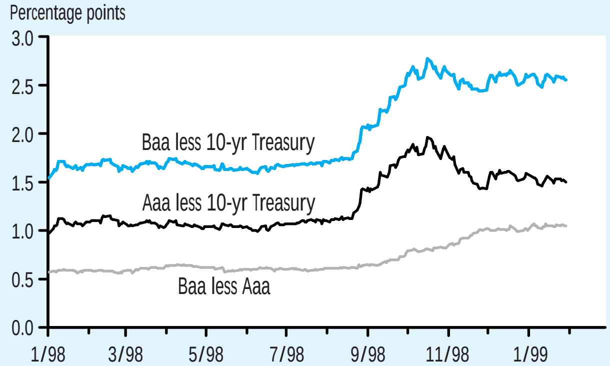


Figure 7

Short-Term Interest Rates

Daily data, January 1998 to January 1999

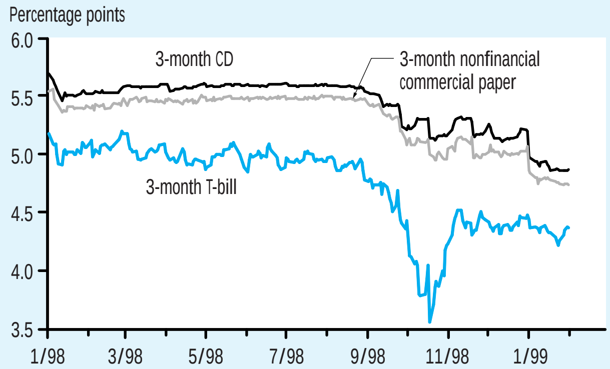
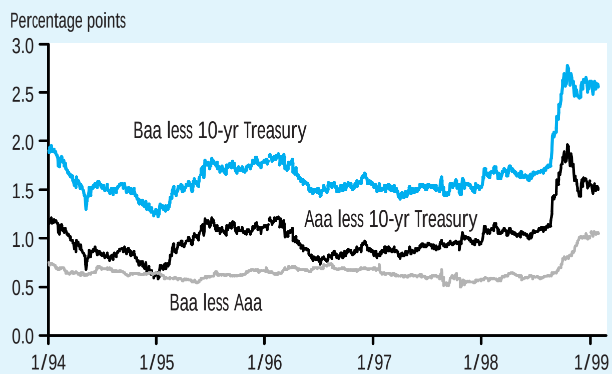


Figure 8

U.S. Bonds Market Quality Spreads

Daily data, January 1994 to January 1999



spread between Aaa and Baa-rated yields. Yield spreads among short-term securities similarly increased, as Figure 7 illustrates by plotting the three-month Treasury bill yield against average rates on three-month bank certificates of deposit and three-month nonfinancial commercial paper. Finally, Figure 8 shows that, by the standard of the previous five years, bond market yield spreads during the fall of 1998 were unusually high.

Along with the flight to quality, anecdotal reports indicated that many relatively low quality borrowers were unable to obtain funds in the money market. Although many borrowers were accommodated by drawing down existing lines of credit at commercial banks, a special survey of senior bank loan officers, conducted by the Federal Reserve in September, indicated that banks had tightened their standards for loans to large firms. According to the survey, "The banks that reported having tightened their lending standards and terms most commonly attributed their decision to a less favorable economic outlook and a worsening of industry-specific problems, as well as a reduced tolerance for risk." Thus the survey results were consistent with the evidence from credit markets that lenders were increasingly fearful about the prospects for continued economic expansion in the United States, and had become less willing to take financial risks.

In light of growing instability in financial markets and a weakened outlook for continued domestic expansion, the FOMC voted to adopt a more stimulative monetary policy by reducing its federal funds rate target from 5 1/2 percent to 5 1/4 percent. "In the Committee's discussion of current and prospective economic conditions, members focused on developments that pointed to the potential for a significant weakening in the growth of spending." The members concluded that "the downside risks to the domestic expansion appeared to have risen substantially in recent weeks." And, "It was clear that the contagious effects of international economic and financial turmoil had markedly increased the downside threat to the domestic expansion."

In considering policy, the FOMC discussed the continued rapid growth of monetary aggregates. While it was suggested that "rapid growth of key monetary aggregates, including M2, over a period of several quarters was a worrisome element in the outlook for inflation," surges in the money stock during the most recent weeks were seen as likely caused by the flight to quality and increased demand for liquidity. Thus, policymakers concluded "an easing policy action at this point could provide added insurance against the risk of a further worsening in financial conditions and a related curtailment in the availability of credit to many borrowers."

Thus the sudden instability in global financial markets had led the FOMC to reevaluate the risks to continued economic expansion in the United States. Prior to the onset of financial instability, higher inflation was viewed as the most likely threat to continued economic growth. Inflation imposes serious economic costs, and history indicates that the more entrenched inflation becomes, the more difficult it is to bring down. The sudden threat to domestic financial markets and economic activity from abroad, however, reduced the risk of an immediate increase in inflation. By increasing the cost and reducing the availability of credit to private borrowers, as well as by increasing uncertainty about the economic outlook, financial instability threatened to slow U.S. economic activity appreciably. Thus the Fed sought to ensure an ample supply of liquidity to financial markets to counteract this threat.

October 15 Conference Call. When the FOMC voted to reduce its federal funds rate target on September 29, it also approved a directive tilted toward additional easing. Further deterioration of financial conditions in the ensuing two weeks led the FOMC to approve a second 25 basis point reduction in the funds rate target to 5 percent. The committee concluded that additional stimulus was needed because

> … risk aversion in financial markets had increased further since the Com-

> mittee's meeting in September, raising volatility and risk spreads even more, eroding market liquidity, and constraining borrowing and lending in a number of sectors of the financial markets. Although indications of any softening in the pace of the economic expansion across the country remained sparse, the widespread signs of deteriorating business confidence and evidence of less accommodative domestic financial conditions suggested that the downside risks to the expansion had continued to mount.

In conjunction with the federal funds rate target reduction, the Board of Governors approved a reduction of Reserve Bank discount rates from 5 percent to $4^{3}/_{4}$ percent.

November 17. In reviewing the state of financial markets and the latest information about the prospects for continued economic expansion at its meeting on November 17, the FOMC observed that while financial market "strains" had moderated since mid-October, "uncertainty remained high and relatively illiquid conditions persisted." Moreover, while recent data indicated that the economy was continuing to grow rapidly, the FOMC staff forecast "considerable slowing" on the horizon, and FOMC members "generally agreed that the economy appeared to be headed toward slower growth." And, they "believed that the continuing fragility of financial markets and the increased scrutiny of the credit quality of borrowers … posed a considerable downside risk to the expansion." Because of this, the FOMC elected to ease policy once again by reducing its target federal funds rate 25 basis points to $4^{3}/_{4}$ percent. The committee concluded that this move would "complete the policy adjustment to the changed economic and financial climate that had emerged since midsummer and would provide some insurance against any unexpectedly severe weakening of the expansion." Moreover, "most members saw little risk that a modest easing would ignite inflationary pressures in the economy." Federal Reserve Bank of Cleveland president Jerry Jordan dissented, however, arguing that the additional easing "risked fueling an unsustainably strong growth rate of domestic demand." Easing, he believed, would cause "excessively rapid rates of growth of the monetary and credit aggregates [that] were inconsistent with continued low inflation."

December 22. At their December meeting, FOMC members remain convinced that "The System's policy easing actions since late September had helped to stabilize a dangerously eroding financial situation, and current financial conditions as well as underlying economic trends suggested that needed policy adjustments had been completed." In deciding against acting further, policymakers observed that although financial markets remained "unusually sensitive," domestic financial conditions would support continued economic expansion. Some committee members believed, moreover, that "the risks of inflation appeared to be tilted to the upside." Nonetheless, some slowing of the economy during the next 12 months still was expected and, overall, the outlook for inflation remained "favorable." Hence, all FOMC members agreed that policy was best left unchanged at this meeting.

CONCLUSION

Like 1997, 1998 proved to be a year of outstanding economic performance for the United States—rapid output and employment growth, rising real wages, and low, stable inflation. This strong performance reflected productivity gains that enabled the real earnings of labor to rise, while both unemployment and inflation fell. Arguably, monetary policy has encouraged the economy's strong performance by reducing inflation to a low level, and during 1998, policymakers were keenly interested in maintaining a lid on inflation to promote continued economic expansion. Thus, in the first half of 1998, high levels of domestic spending, tight labor markets, and rapid growth of monetary aggregates caused the FOMC to signal that its next overt policy move would likely be tightening. Two members of the FOMC were, at the same time, sufficiently concerned about an increase in inflation to vote (at least once) in favor of immediate tightening.

Attention changed abruptly in the autumn, when economic and financial instability abroad precipitated a scramble for liquidity and safety affecting U.S. financial markets. The FOMC accommodated the increased demand for liquidity by easing policy on three occasions. These actions were taken not just to assuage financial markets, but to preserve the ongoing economic expansion. The fourth quarter witnessed rapid growth of real output, as well as continued low inflation, and financial markets calmed. Chairman Greenspan testified in February 1999 that "Our economy has weathered the disturbances with remarkable resilience," and argued that "The Federal Reserve must continue to evaluate … whether the full extent of the policy easings undertaken last fall to address the seizing-up of financial markets remains appropriate as those disturbances abate." (The Federal Reserve's Semiannual Report on Monetary Policy, Testimony of Chairman Alan Greenspan before the U.S. Senate Committee on Banking, Housing, and Urban Affairs, February 23, 1999). As Chairman Greenspan implied, the challenge for policymakers is to look forward and continually reevaluate whether the stance of monetary policy remains appropriate as conditions change. In 1998, the FOMC moved decisively when financial disturbances threatened the U.S. expansion, but held off earlier in the year when traditional indicators suggested that inflation might increase. Throughout 1998, economic conditions remained favorable. But, in light of the old saying that the lag effects of monetary policy on the economy are "long and variable," only time will tell whether the policy actions taken in 1998 will turn out to be consistent with preserving price stability and maximum sustainable economic growth over the long run.

REFERENCES

Anderson, Richard G. "Is M2 Growth on a New Track?" *Monetary Trends* (May 1997).

Barro, Robert J. "Inflation and Growth," this *Review* (May/June 1996), pp. 153-69.

Bruno, Michael, and William Easterly. "Inflation and Growth: In Search of a Stable Relationship," this *Review* (May/June 1996), pp. 139-46.

Dewald, William G. "M2 Velocity Looks to be on a New Track," *Monetary Trends* (October 1998).

Griliches, Zvi. "Productivity, R&D, and the Data Constraint," *American Economic Review* (March 1994), pp. 1-23.

Orphanides, Athanasios. "Monetary Policy Evaluation with Noisy Information," Board of Governors of the Federal Reserve System, Finance and Economics Discussion Series no. 1998-50, October 1998.

Yoo, Peter. "The FOMC in 1997: A Real Conundrum," this *Review* (September/October 1998), pp. 27-40.

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Price-Level Uncertainty and Inflation Targeting

Robert Dittmar, William T. Gavin, and Finn E. Kydland

International discussions of monetary policy today often are focused on inflation targeting. At least eight central banks around the world have now adopted explicit targets for inflation. In all of these cases, the central bank has a flexible policy process that focuses on inflation but also cares about other variables, such as employment, output growth, and the behavior of a short-run policy guide such as the federal funds rate or an exchange rate.[1] Even among countries that do not have explicit inflation targets, their policy behavior has been portrayed as if they have inflation targets. Taylor (1993) explains how U.S. monetary policy can be characterized as a rule for targeting inflation. In this rule, the Federal Reserve systematically adjusts the federal funds rate in response to deviations of output from potential and inflation from an implicit target.

One of the perceived advantages of inflation targeting is that a long-run price stability goal may be pursued in combination with other short-run objectives, usually for real output. There is some confusion about this point in the literature. In a chapter titled "The Rationale for Inflation Targeting," Bernanke et al. (1999) argue:

> …the increased emphasis on controlling inflation arises not because unemployment and related problems have become less urgent concerns, but because economists and policy-makers are considerably less confident today than they were thirty years ago that monetary policy can be used effectively to moderate short-run fluctuations in the economy, (page 10).

Later in the same chapter, they clearly define inflation targeting to be a framework with multiple short-run objectives:

> *If* inflation targeting were to be treated as a policy rule in the classical sense (which, again, we do not think it should be), it would indeed be open to some serious criticisms. First, the idea that monetary policy literally has no goals other than to control inflation would find little support from the public, from central bankers, or from monetary economists. Second, given that governments and central banks do care about production, employment, exchange rates, and other variables besides inflation, treating inflation targeting as an ironclad policy rule could lead to very poor economic outcomes.

As the two quotes suggest, inflation targeting is appealing to those who think that having a target for inflation focuses policymakers' attention on the inflation objective as well as those who want rule-like policy, but still believe that the central bank can achieve multiple objectives. In this paper we examine inflation-targeting regimes to see how having multiple objectives affects uncertainty about future price levels.

We make two points about commonly proposed rules for inflation targeting. First, we argue that there is a great deal of uncertainty about the price level and inflation inherent in current proposals to target inflation. We show that the degree to which the central bank cares about the real economy can have a large impact on price-level (and inflation) uncertainty. Indeed, we find that

[1] See Bernanke et al. (1999) and Siklos (1999) for recent descriptions of inflation-targeting regimes.

Table 1

Inflation Statistics in the G-10 plus Switzerland — Different Time Periods

Country	1957:1 - 97:4 Mean	Std. Dev.	1957:1 - 73:1 Mean	Std. Dev.	1973:2 - 84:4 Mean	Std. Dev.	1985:1 - 97:4 Mean	Std. Dev.
Belgium	4.19	3.52	3.05	2.44	7.82	3.57	2.33	1.77
Canada	4.64	3.72	2.83	2.40	8.84	3.07	3.07	2.34
France	6.01	4.85	5.30	5.05	10.76	2.91	2.58	1.42
Germany	3.21	2.72	2.95	2.78	4.57	2.48	2.30	2.41
Italy	7.75	6.69	3.73	3.41	16.13	5.85	5.11	2.19
Japan	4.59	5.71	5.04	4.40	7.56	7.67	1.35	2.72
Netherlands	4.21	4.52	4.62	5.77	6.26	3.29	1.84	2.04
Sweden	6.13	6.94	4.63	8.26	9.90	5.85	4.57	4.42
Switzerland	3.42	3.12	3.50	2.68	4.34	3.96	2.49	2.49
United Kingdom	6.82	6.80	4.33	4.10	12.77	8.42	4.51	4.03
United States	4.47	3.36	2.79	1.86	7.99	3.80	3.35	1.55
Average Across Countries	5.04	4.72	3.89	3.92	8.81	4.62	3.05	2.49

NOTE: Std. Dev. is the standard deviation of inflation measured quarterly at annual rates.

the magnitudes of uncertainty that prevailed across the G-10 countries throughout the last four decades are the expected consequence of commonly proposed inflation-targeting regimes. Second, we show that if central banks want both to stabilize business cycle fluctuations and to achieve price stability, then it may be useful to adopt a long-term objective for the price level. A long-run price-level objective can be implemented in a way that represents a minor change in the way central banks currently implement policies oriented around inflation objectives. Yet, this minor change in the central bank's decision-making process has the potential to deliver price stability.

In this paper, we deliberately chose a model from the inflation-targeting literature that implies a tradeoff between output and inflation variability. In preliminary work for this article, we used the general equilibrium model of Gavin and Kydland (1999), which was modified to include a central bank that targets inflation or the price level. Also, the central bank incorrectly believes that the Phillips Curve represents a viable framework for making monetary policy. In this general equilibrium model, the classical dichotomy approximately holds, so there is no measurable tradeoff between inflation and output variability. In the final analysis, we chose to use the simple Phillips Curve model as the representation of the economy (rather than the general equilibrium model) for two reasons. First, the results for inflation and the price level from the general equilibrium model are almost identical to those presented in this article. Second, since monetary policymakers do not normally use the general equilibrium framework, we want to make it clear that our results do not depend on it.

THE INFLATION EXPERIENCE IN THE G-10: 1957-1997

Since World War II, the monetary policies of the leading economies of the world have framed their discussion about price stability in terms of inflation, not the price level. Figure 1 shows the inflation rates for the G-10 countries (including Switzerland). Generally, these countries were part of the fixed exchange-rate regime set up at Bretton Woods after WWII. As Figure 1 shows, inflation rates were relatively low and close together during this period. By March 1973, all of the countries began to experience higher and more variable inflation. There were a variety of monetary experiments; some countries began to target monetary aggregates, others joined together in smaller groups to fix exchange rates. By 1985, all of the countries appear to have gained more control over inflation. The period following 1985 appears to be one of relatively stable inflation, more like the period under the Bretton-Woods Agreement.

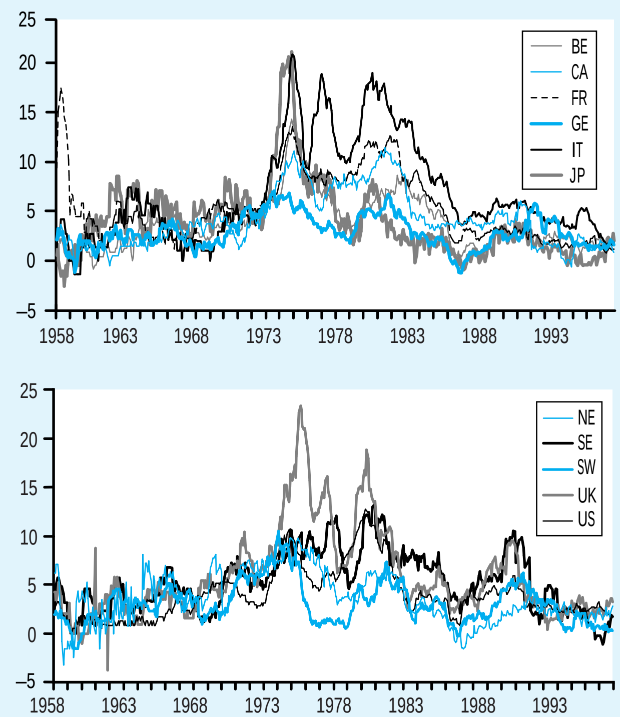
Table 1 depicts the average inflation rates for the full 40-year period and for three subperiods. The unweighted average inflation rate in these 11 countries for this 40-year period was 5.04 percent and the standard deviation of quarterly inflation was 4.72 percent at an annual rate. During the first period, 1957:Q2 to 1973:Q1, inflation averaged just 3.89 percent with an average quarterly standard deviation of 3.92 percent (annual rate). In the period following the breakdown of the Bretton-Woods agreement, average inflation rose to 8.81 percent and the standard deviation averaged 4.62 percent. Since 1984, the average inflation rate has dropped dramatically to 3.05 percent, almost a full percentage point below the average during the period of Bretton Woods. The average standard deviation of inflation also has been much lower at 2.49 percent.

The inflation rates shown in Figure 1 were associated with widely varying behavior of price levels. Figure 2 shows the Consumer Price Index (CPI), normalized to one in January 1957, for each of the G-10 countries plus Switzerland. Italy had the highest average inflation (7.75 percent annual rate) throughout the last 40 years. The lowest average inflation was in Germany where the inflation rate averaged 3.21 percent during the full period. The broad range of experience shown in Figure 2 provides a frame of reference for considering the magnitude of uncertainty about the price level implied by alternative monetary policy regimes.

Figure 1

CPI Inflation for the G-10 Countries

Monthly data, year over year growth



Levels Versus Growth Rates

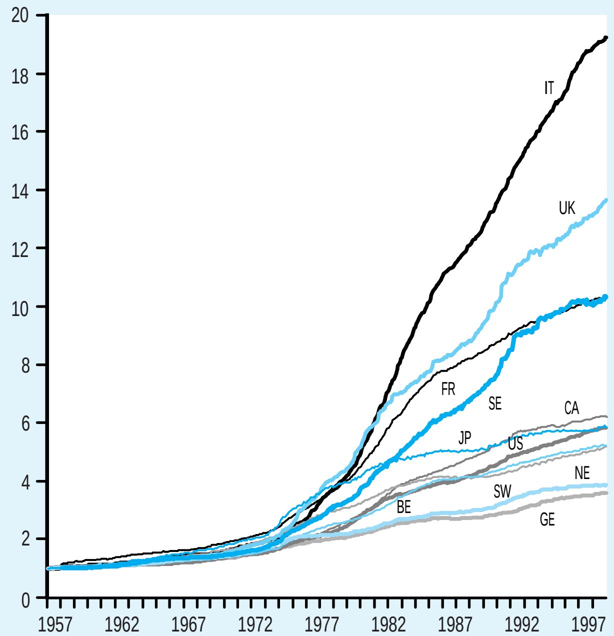
A period-by-period inflation-targeting regime causes the error in forecasts of the price level to rise with the forecast horizon. Price-level targeting has been recommended as a means of reducing long-term uncertainty about the price level. McCallum (1997) dismisses the notion of price-level targeting by comparing the log of the price level that followed a pure random walk to a preset target path. Figure 3 shows the amount of price-level uncertainty inherent in a policy that makes the price level a pure random walk with annual drift of 5 percent inflation, approximately the post-war average inflation for the G-10. We assume (as did McCallum) that the random walk has an unpredictable component at the quarterly frequency that is approximately equal to the standard deviation of one-step ahead forecast errors for the United States throughout 1954-91 (0.0045 percent at a quarterly rate).

After 20 years, the 95-percent confidence interval for the price level under the random walk assumption is plus and minus 8 per-

Figure 2

The CPI for the G-10 Countries

Indexed to 1 in January 1957



cent of the path for the price level implied by a deterministic 5 percent inflation. After 40 years, the 95-percent confidence interval rises to plus and minus 12 percent. Clearly, the outcome for the price level under this random walk assumption is much more certain than the range of uncertainty implied by the G-10 experience. The pure random walk implicitly assumes that the central bank can commit to an inflation target, ignore other variables, and control inflation up to a small random error. In the rest of the paper, we explore what happens when we drop the assumption that the central bank ignores other variables.

INFLATION TARGETS AND THE PHILLIPS CURVE

In this section we derive optimal policy rules using alternative specifications of a central bank loss function. A simple Phillips Curve model calibrated to approximately match econometric estimates in Rudebusch and Svensson (1998) portrays the economy. Not surprisingly, our optimal policy function looks much like a class of inflation-targeting rules that have been proposed by a variety of authors.[2]

To examine the price level implications of inflation-targeting rules we adapt a Phillips Curve model used by Svensson (1997a, 1997b). The model has three main elements: a multi-period objective function for the central bank, an aggregate supply equation, and a rational expectations assumption.

As in Svensson (1997b), the central bank minimizes a quadratic loss function

$$(1) \quad L^A = \sum_{t=0}^{\infty} \beta^t \left(\lambda y_t^2 + (\pi_t - \pi^*)^2 \right),$$

where y_t is the deviation of output from the target level and $(\pi_t - \pi^*)$ is the deviation of inflation from the central bank's inflation target. The term, λ, gives the weight on output gap relative to the weight on inflation in the central bank's loss function. As shown by Svensson (1997b), the real economy in this model behaves marginally better (the variability of the output gap is lower) when the central bank cares more about output stabilization.

In this article, the economy is represented by a short-run aggregate supply curve with persistence in the output gap:

$$(2) \quad y_t = \rho y_{t-1} + \alpha(\pi_t - \pi_t^e) + \varepsilon_t,$$

where ρ determines the persistence in the output gap, α determines the response of the output gap to unanticipated inflation, and ε_t is an i.i.d. technology shock with mean zero and variance σ_ε^2.

We used this model in Dittmar et al. (1999) to challenge an assumption often made by those who analyze monetary policy in a Phillips Curve framework. The assumption is that price-level targeting would cause large output variability. With a highly persistent output gap, the inflation-output variability tradeoff is better with price-level targeting than it is with inflation targeting.

The inflation-targeting rule derived in Dittmar et al. (1999) is given by:

[2] For a recent discussion of this literature, see Cecchetti (1998) and Rudebusch and Svensson (1998).

$$(3)\quad \pi_t^A = p_t^A - p_{t-1} = \pi^* - \frac{\alpha\lambda\rho}{1-\beta\rho^2}\, y_{t-1} - \frac{\alpha\lambda}{1-\beta\rho^2+\alpha^2\lambda}\,\varepsilon_t,$$

where the superscript A refers to the price or inflation-rate target that is optimal, given equations 1 and 2.

Uncertainty About the Price Level and Output Stabilization. This section reports the results of computational experiments that calculate the amount of price-level uncertainty expected in policy regimes that are distinguished by alternative values of λ, the relative weight on output stabilization in the central bank's loss function. In the model there is a tradeoff between persistence in the output gap and the weight the central bank puts on output in its loss function. If output is more persistent, inflation is more variable for a given value of λ. In the computational experiments we set ρ equal to 0.9 and α equal to 0.5. These assumptions imply a Phillips Curve with a slope of 0.2 when the Phillips Curve is written in terms of the inflation rate. Using this form, Rudebusch and Svensson (1998) estimate the slope to be 0.14. We could match this number by increasing the persistence of the output gap or the slope of the Phillips Curve. Doing either would increase the uncertainty about the price level implied inflation targeting, so we decided to stay with the assumptions that are used in our earlier paper. We assume that the interest rate is 4 percent at an annual rate, so the quarterly discount factor is approximately 0.99. The standard deviation of the random error in the aggregate supply function 2 is assumed to be 0.75 percent at a quarterly rate. This calibration results in an output gap series that has a standard deviation that is about half as large as observed in U.S. data. Again, increasing the assumed variance of the supply shock would tend to increase uncertainty about the long-term path of the price level for a given value of λ.

Figure 3

Price Level Uncertainty with a Random Walk Inflation Policy

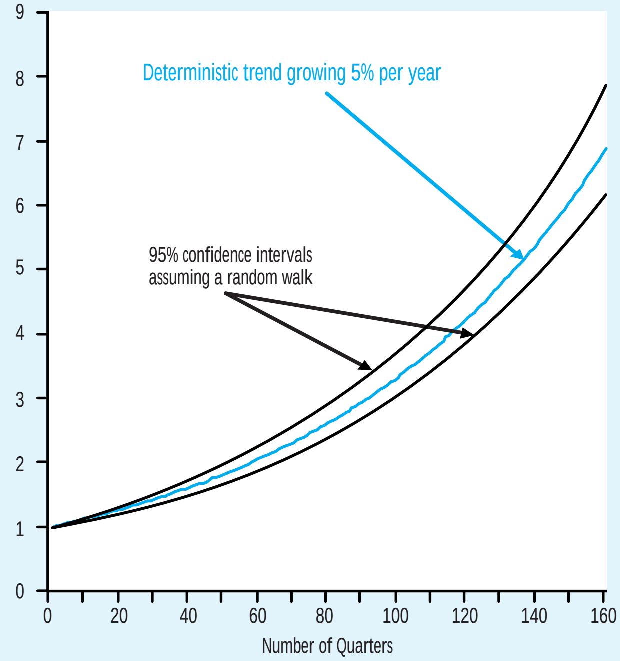


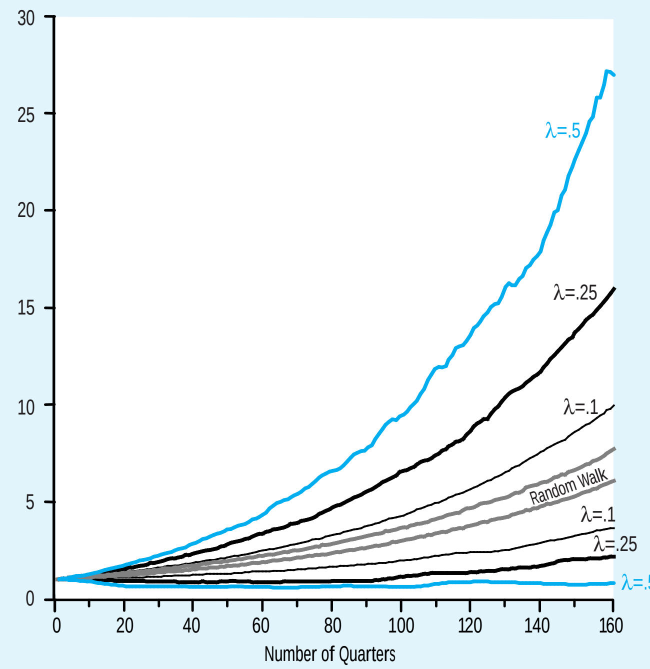
Figure 4 shows the 95-percent confidence intervals for the price levels expected in our three experiments as well as for the random walk experiment shown in Figure 3. The three cases include λ equal to 0.5, 0.25, and 0.1. These values for λ correspond to coefficients on the lagged output gap in the policy rule equal to 1.13, 0.57, and 0.23, respectively. As shown in Figure 4, with $\lambda = 0.5$, the 95-percent bounds encompass the high inflation of Italy and the low inflation experience of Germany. With $\lambda = 0.25$ we still have an enormous range of uncertainty about the price level. Only in the case of Italy does the actual CPI lie above this range. Since the only source of uncertainty is from output, setting $\lambda = 0$ in this model would result in a deterministic path for the price level as shown in Figure 3. Even setting λ as low as 0.1 would result in much greater uncertainty than implied by the random walk.

How does one reconcile the recent rel-

Figure 4

Price Level Uncertainty with Inflation Targeting and Concern about the Output Gap

(95% confidence intervals under alternative assumptions about policy)



ative stability and convergence of inflation rates in the G-10 with our model? There are at least two ways consistent with our model. First, policymakers actually may be cognizant of the past deviations from inflation targets and attempt to offset them in the future. Second, an inflation target probably focuses attention on price stability and reduces the weight on the real economy. In practice, inflation targets have been useful because they give central banks political cover to pursue anti-inflation policies even in times when the economy is weak. And third, central banks around the world have been lucky; that is, the deviations of output from trend have been relatively small since 1990. The challenge for monetary policy, here and abroad, is to adopt policy institutions that will continue to deliver low and stable inflation rates.

AN ERROR-CORRECTION RULE WITH A LONG-TERM PRICE OBJECTIVE

One way to reduce uncertainty about future inflation is to adopt a long-term objective for the price level. The benefits of having such a long-term goal can be lost in analysis that portrays the central bank's options as one of two extremes: either inflation targets or price-level targets. In this section, we analyze an inflation-targeting procedure that is anchored to a deterministic path for the price level. We could define such a policy rule just by adding an error correction term to our inflation-targeting rule, equation 3. As you will see, this is in fact what happens if the policymaking committee is made up of two types of individuals: type A, who want to target inflation, and type B, who want to target the price level.

If the policymaker cares about deviations of the price level rather than the inflation rate, the natural logarithm of the price level replaces the inflation rate in the loss function. We reformulate the objective function as below:

$$(4)\quad L^B = \sum_{t=0}^{\infty} \beta^t \left(\lambda y_t^2 + (p_t - p_t^*)^2 \right),$$

where the target path for the price level may or may not be constant. Combining this objective function with the aggregate supply equation leads to the following decision rule for price-level targeting:

$$(5)\quad p_t^B = p_t^* - \frac{\alpha\lambda\rho}{1-\beta\rho^2} y_{t-1} - \frac{\alpha\lambda}{1-\beta\rho^2+\alpha^2\lambda} \varepsilon_t,$$

where the superscript *B* indicates the price-level target that is optimal for a policymaker who has the objective function described in equation 4.

Suppose that there is a policymaking committee that includes a mixture of types A and B. The monetary policy rule can be rewritten as a combination of the two rules:

$$p_t = \delta p_t^A + (1-\delta) p_t^B. \tag{6}$$

When $\delta = 1$, all the policymakers want to target inflation and the central bank is following the rule given in equation 3. When $\delta = 0$, nobody on the committee wants to target inflation and the central bank is following a price-level rule. When δ falls between 0 and 1, there are some of both types on the committee and the central bank is following a combination rule that is equal to the inflation-targeting rule with an error-correction term on the deviation of the price level from a target path. To show this, we note that $p_t^* = \pi^* + p_{t-1}^*$ and substitute equations 3 and 5 into 6 to get

$$\pi_t = \pi^* - \frac{\alpha\lambda\rho}{1-\beta\rho^2} y_{t-1} - \frac{\alpha\lambda}{1-\beta\rho^2+\alpha^2\lambda}\varepsilon_t + (1-\delta)(p_{t-1}^* - p_{t-1}). \tag{7}$$

Equation 7 has the same form as equation 3 except for the addition of the error correction term.[3] This general form of the model is used to examine the effects of changing the relative weight on the alternative rules.

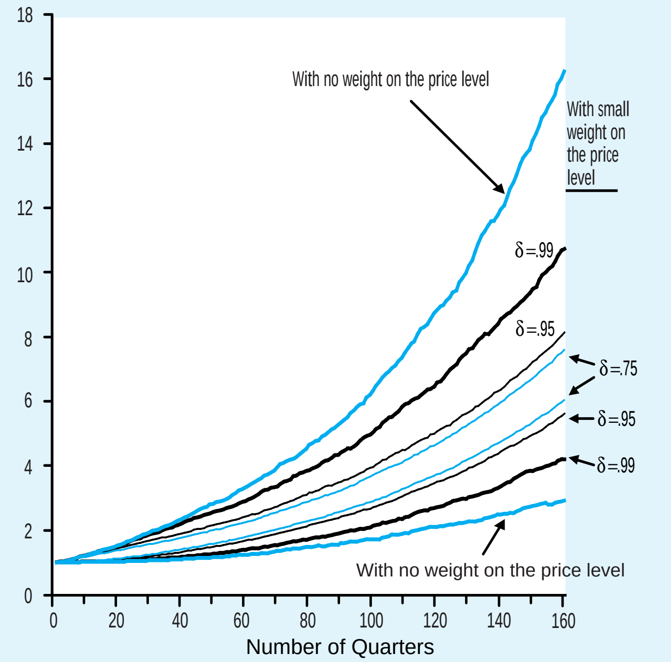
Uncertainty About the Price Level with the Mixed Rule. In computations below, we set $\rho = 0.9$, $\alpha = 0.5$, $\lambda = 0.25$, and $\sigma_\varepsilon = .0075$. In all of our experiments the price level objective is a deterministic path growing smoothly at 5 percent per year (as shown in Figure 3). The experiment was run four times, each with alternative values of the error correction parameter, $(1–\delta)$: 0, 0.01, 0.05, and 0.1. Each experiment consisted of 1,000 repetitions, each drawing a new set of random shocks to output—the only source of uncertainty.[4]

Figure 5 shows the results. The highest and lowest lines represent the 95-percent confidence intervals for the expected position of the price level with $(1–\delta) = 0$ and $\lambda = 0.25$ (also shown in Figure 4). Setting

Figure 5

Inflation Targeting with a Long-Run Price Objective

(95% confidence intervals with l =.25)



$(1–\delta)$ equal to 0.01 eliminates much of the uncertainty about the price level. If we set it as high as 0.1, we find the 95-percent bounds are about equal to plus and minus 12 percent, the expected bounds for the random walk after 40 years. Note that at 20 years, the 95-percent confidence bounds also are plus and minus 12 percent, while random walk confidence intervals were plus and minus 8 percent. The confidence bounds stabilize at a constant percent of the price level with a nonzero error-correction parameter. With a random walk the uncertainty grows with the time horizon.

OBJECTIONS TO PRICE-LEVEL TARGETING

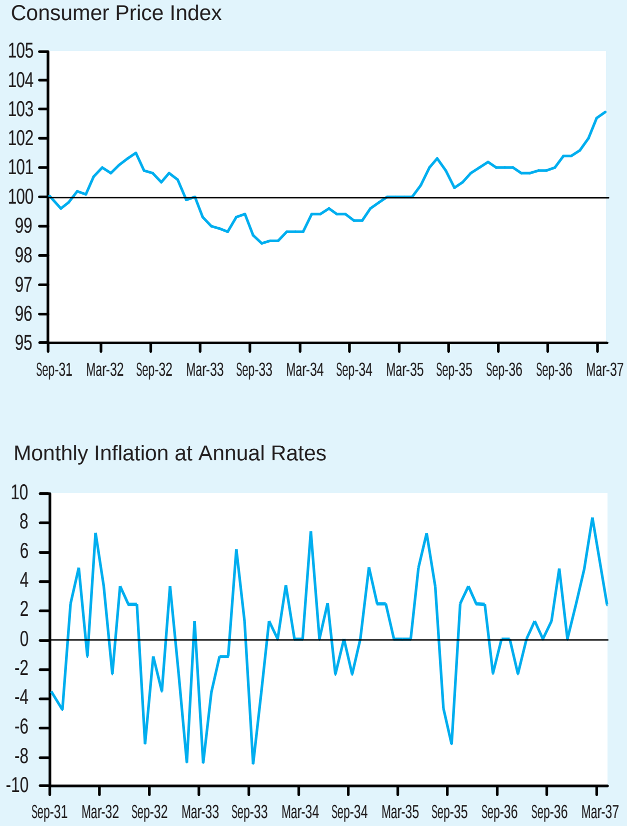
Kiley (1998) objects to the Neoclassical form of the Phillips Curve used by Svensson (1997a,b)—and in this paper. He suggests that if Svensson had used a New Keynesian specification he would

[3] Black, Macklem, and Rose (1997) report results using the Bank of Canada's policy model in which some part of the efficient frontier in an output-inflation variability tradeoff is determined using an error correction framework with a long-term price-level objective.

[4] We used a common seed for the random error so the sequence of random errors was identical for each of the four separate experiments.

Figure 6

Sweden's CPI target in the 1930s



not have found such a favorable result for price-level rules. Dittmar and Gavin (1999) show that this is not the case. They show that using the New Keynesian Phillips Curve actually strengthens the case for price-level targeting relative to the Neoclassical specification.

Simulation results using econometric models typically find targeting the price level destabilizes output, often in dramatic fashion. These papers have assumed backward-looking expectations for inflation. For example, see the results and references in Haldane and Salmon (1999). In our judgment, the Lucas (1976) critique is very important for this issue. For example, when Black et al. (1997) and Williams (1999) use econometric models with forward-looking inflation expectations, they find that some forms of price-level targeting appear to reduce inflation variability (relative to short-run inflation targeting) without increasing output variability.

There also is some confusion about terms in the debate over price-level targeting. It is important to distinguish between prolonged bouts of deflation, such as the one that occurred in the United States during the depression, and the normal fluctuations in a price index, which are caused by measurement problems and real shocks. Deflation cannot persist unless it is accompanied by a shrinking money supply (validated by monetary policy decisions). Fischer (1994) and Cecchetti (1998) argue that with a constant price-level target, you will get deflation half the time. But if the deviations of the price level from a target path are the result of real factors and not the result of monetary policy decisions, then they are unlikely to grow larger over time. Our results show that only small corrections would be needed to return the price level to its target path.

The belief that having a policy regime with a long-term price-level objective would be bad comes from the assumption that monetary policy actions, even those that are part of a systematic response to shocks, can have large real effects. We are skeptical about this assumption, but realize that it is widely shared in the community of policy advisors. That is why we choose the Phillips Curve approach in our analysis and why we chose such small values for the error-correction parameter in the previous section. The small value means that the short-term reaction to the deviations of the price level from the long-run path will be small relative to the central bank's reaction to the output gap. Of course, if the price-level gap becomes large, then even with a small error-correction parameter, the required policy reaction may approach the scale of response implied for output gaps.

THE SWEDISH MONETARY EXPERIMENT

There is at least one case of a price-level target in history. It occurred during a period when there were large real shocks. In Sep-

Table 2

Sensitivity of output gap and in ation variability to alternative values of λ and δ

Alternative values of λ	Output Gap: Standard Deviation	Output Gap: First Order Autocorrelation	Inflation: Standard Deviation	Inflation: First Order Autocorrelation	Correlation: inflation and the output gap
(δ = 1.0)					
0.50	0.98	0.88	1.24	0.88	–1
0.25	1.22	0.88	0.77	0.88	–1
0.10	1.42	0.88	0.36	0.88	–1
Alternative values of δ					
(λ = 0.25)					
0.99	1.22	0.88	0.76	0.87	–0.99
0.95	1.22	0.88	0.68	0.84	–0.89
0.90	1.22	0.88	0.61	0.79	–0.78

tember 1931, the Swedish Riksbank left the gold standard and began to target the Consumer Price Index (CPI). The CPI was normalized to 100 in September and stayed near 100 until April 1937—when the directors of the Riksbank decided to abandon the CPI objective, rather than let the currency appreciate *vis-à-vis* the pound Sterling.[5] Figure 6 shows the CPI levels and inflation rates from September 1931 to March 1937. The top panel shows that the price level reached a peak of 101.5 in July 1932 before falling to a trough of 98.4 in October 1933. The index began a gradual climb and did not reach a new high until December 1936 (101.6). It rose above 102 during the first three months of 1937, leading to the abandonment of the target in April (when it rose to 104).

The bottom panel of Figure 6 shows the monthly inflation rate (annualized). In these 67 months, the Riksbank recorded 32 months of inflation, 21 months of deflation and 14 months when the CPI was unchanged. The question is how one should think about the monthly changes. Fischer (1994) and Cecchetti (1998) imply that such deflation is likely to have negative consequences for the real economy. As a matter of record, some economists of the day blamed Sweden's high unemployment on the Riksbank's decision to target the CPI.[6] Looking back, it seems more likely that Swedish monetary policy was a success. Sweden had much less deflation during 1932 and 1933 than did most of Europe. They had one of the least severe depressions, not only in Europe, but also around the world. Bernanke (1995) concludes that it was the decision to go off the gold standard and prevent deflation that was the key to Sweden's success.

As the Swedish example shows, it is important to distinguish between the normal random variation in the price level that should be expected in a regime of price stability (shown in Figure 6) and the persistent deflation in countries that did not go off the gold standard. In the United States, the CPI fell at an average annual rate of 9.7 percent between September 1931 and April 1933.[7] That deflation was associated with failing banks and a collapsing money supply. The recurring bouts of inflation and deflation in Figure 6 most likely are due to real disturbances that continually buffet markets.[8]

We have argued that the policy adjustments that would be needed to achieve a price-level objective would not have to be large. One way to gauge the size of policy

[5] Fisher (1934), Jonung (1979), and Berg and Jonung (1998) provide details about this episode.

[6] See Berg and Jonung (1998), page 33.

[7] These data were taken from Chart I in Fisher (1934), page 326.

[8] Jonung (1979) concludes that money-supply growth was relatively stable during this period. Berg and Jonung (1998) report that there were no reversals of the bank discount rate after 1931.

adjustments is to multiply the error-correction parameter (for this exercise, assume it is equal to 0.1) by the percent deviation of the price level from target. In the case of Sweden during 1932, that deviation peaked around 1.5 percent, suggesting a policy-correcting deflation of 0.15 percent. In December of 1936, the Riksbank would have had to change policy in a way that would encourage a deflation of 0.16 percent. By April 1937, the CPI was at 104 and would have required a policy setting intended to reduce the price level by 0.4 percent at an annual rate. These policy-induced changes are more than an order of magnitude smaller than the monthly standard deviation of the inflation rate. In our model, they are effective because they represent a small persistent correction that stays in place until the price level returns to target.

PRICE LEVEL OBJECTIVES AND CREDIBILITY

In principle, any conclusion about the size of adjustments will depend upon how the central bank implements the price-level objective and how the economy works. Using a linear, rational expectations framework, Balke and Emery (1994) show that having a long-term price objective is likely to result in less, not more, variability of short-run inflation. They also show that a long-run price-level objective does not interfere with short-run output stabilization. Both of these results hold in this model. Table 2 shows the output gap and inflation statistics associated with different relative weights on the output gap and different weights on the long-term price-level objective. Putting more weight on the output gap reduces the variability of the output gap and raises the variability of inflation. For a given weight, λ, however, raising the relative weight on the long-term price objective has no effect on the short-run variability of the output gap, but reduces the short-run variability of inflation. In practice, adopting a long-term price objective may enhance the efficacy of short-run output stabilization policy, if it makes the price stability goal credible and concentrates people's expectations about long-run average inflation.

There is some concern that a small error-correction response to price-level deviations would not be credible. We think the credibility would be enhanced in spite of a small error-correction parameter because the policy would be transparent. In the context of the United States today, our proposal would be implemented by having the Federal Open Market Committee (FOMC) debate and decide on a long-term inflation objective (say four to five years). Once the debating and voting is done, the FOMC report to Congress would include a multiyear path for the chosen index growing at the desired inflation rate as well as the annual targets for money and credit. Deciding on a long-term objective would be the major change in policy. On a daily basis, the Open Market Desk at the New York Fed would continue to operate as today, buying and selling Treasury debt to maintain a target for the federal funds rate. The minor, but important, difference would occur at FOMC meetings where policymakers would monitor the price level relative to its long-term objective. At every FOMC meeting there would be some members who would support shading the policy decision to encourage the price level to return to its long-run target path. The existence of a public commitment would give those members' opinion more weight in the final vote. As we saw in experiments with the error-correction model, the change in short-run behavior would be difficult to measure in the quarterly statistics, but the status of the price stability objective would not.

CONCLUSION

We show that when the central bank cares about the real economy, an inflation-targeting regime will lead to much more uncertainty about inflation and the price level than has been commonly suggested. We find that the magnitudes of uncertainty about inflation that prevailed throughout the last four decades are the expected consequence of commonly proposed inflation-targeting regimes. The adoption of inflation-targeting regimes around the world has been associated with lower inflation and less variable inflation. The lower variability probably indicates that central banks have begun to put less weight on the state of the real economy as they focus more sharply on the inflation objective.

For policymakers who believe that the central bank can, and should, stabilize the business cycle, it is a drawback of inflation-targeting regimes that in order to reduce inflation uncertainty, the central bank must ignore the state of the real economy. We show how this drawback may be overcome by putting just a small weight on a long-term price level objective. Doing so allows the central bank to concentrate people's expectations about the long-term inflation outcome without necessarily giving up short-run concerns about the real economy.

REFERENCES

Balke, Nathan S., and Kenneth M. Emery. "The Algebra of Price Stability," *Journal of Macroeconomics* (Winter 1994), pp. 77-97.

Berg, Claus, and Lars Jonung. "Pioneering Price Level Targeting: The Swedish Experience 1931-1937," manuscript presented at the Conference on Monetary Policy Rules in Stockholm on June, 12-13 1998.

Bernanke, Ben S. "The Macroeconomics of the Great Depression: A Comparative Approach," *Journal of Money, Credit and Banking*, (February 1995), pp. 1-28.

________, Thomas Laubach, Frederic S. Mishkin, and Adam S. Posen. *Inflation Targeting: Lessons from the International Experience*, Princeton University Press, Princeton, 1999.

Black, Richard, Tiff Macklem, and David Rose. "On Policy Rules for Price Stability," presented at a Bank of Canada Conference, *Price Stability, Inflation Targets and Monetary Policy* on May 3-4, 1997.

Cecchetti, Stephen G. "Policy Rules and Targets: Framing The Central Banker's Problem," *FRBNY Economic Policy Review* (June 1998), pp. 1-14.

Dittmar, Robert, and William T. Gavin. "What do New Keynesian Phillips Curves Imply for Price-Level Targeting?" Manuscript, Federal Reserve Bank of St. Louis, August 1999.

________, ________, and Finn E. Kydland. "The Inflation-Output Variability Tradeoff and Price-Level Targets," this *Review* (January/February 1999), pp. 23-31.

Fischer, Stanley. "Modern Central Banking," in *The Future of Central Banking: The Tercentenary Symposium of the Bank of England*, Capie, Forrest, Charles Goodhart, Stanley Fischer, and Norbert Schnadt, eds., Cambridge University Press, Cambridge, 1994, pp. 262-308.

Fisher, Irving. *Stable Money: A History of the Movement*, New York, Adelphi Company, 1934.

Gavin, William T., and Finn E. Kydland. "Endogenous Money Supply and the Business Cycle," *Review of Economic Dynamics* Vol. 2, No. 2 (1999), pp. 347-69.

Haldane, Andrew G. and Christopher K. Salmon. "Three Issues on Inflation Targets," in *Targeting Inflation: A Conference of Central Banks on the Use of Inflation Targets Organized by the Bank of England, March 9-10, 1995*, Haldane, Andrew G., ed., Bank of England, 1995, pp. 170-201.

Jonung, Lars. "Knut Wicksell's Norm of Price Stabilization and Swedish Monetary Policy in the 1930s," *Journal of Monetary Economics*, (October 1979), pp. 459-96.

Kiley, Michael T. "Monetary Policy under Neoclassical and New-Keynesian Phillips Curves, with an Application to Price Level and Inflation Targeting," Board of Governors of the Federal Reserve System, Working Paper 1998-27, May 20, 1998.

Lucas, Robert E. Jr. "Econometric Policy Evaluation: A Critique," in *The Phillips Curve and Labor Markets*, Brunner, Karl, and Allan H. Meltzer, eds. Amsterdam: North Holland (1976), pp. 19-46.

McCallum, Bennett T., "Issues in the Design of Monetary Policy Rules," NBER Working Paper 6016, April 1997.

Rudebusch, Glenn D., and Lars E. O. Svensson. "Policy Rules for Inflation Targeting" NBER Working Paper 6512, April 1998.

Siklos, Pierre. "Inflation-Target Design: Changing Inflation Performance and Persistence in Industrial Countries," this *Review* (March/April 1999), pp. 47-58.

Svensson, Lars E. O. "Optimal Inflation Targets, 'Conservative' Central Banks, and Linear Inflation Contracts," *American Economic Review* (March 1997a), pp. 98-114.

________. "Price Level Targeting vs. Inflation Targeting: A Free Lunch?" Institute for International Economic Studies, Stockholm University, August 1997b. An earlier version was published in August 1996 as National Bureau of Economic Research Working Paper 5719.

________. "Inflation Targeting as a Monetary Policy Rule," presented at the Conference on Monetary Policy Rules sponsored by the Sveriges Riksbank and the Institute for International Economic Studies, Stockholm University, June 12-13, 1998.

Taylor, John B. "Discretion versus Policy Rules in Practice," *Carnegie-Rochester Conference Series on Public Policy* (December 1993), pp. 195-214.

Williams, John C. "Simple Rules for Monetary Policy," Board of Governors of the Federal Reserve System Finance and Economics Discussion Series 1999-12, February 1999.

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Can Market-Clearing Models Explain U.S. Labor Market Fluctuations?

Victor E. Li

Modern business cycle theories are evaluated on the basis of their ability to explain key empirical features of the post-war U.S. business cycle. The failure of nonmarket-clearing macro models to account for the rise of unemployment and inflation in the early 1970s led to the rise of New Classical explanations of the business cycle. In particular, the real business cycle (RBC) approach has received much attention in economics because it provides microeconomic foundations for macroeconomic behavior and emphasizes the importance of a quantitative evaluation of the theory's predictions. RBC theory shows how fluctuations in macroeconomic aggregates (recessions and booms) can result from the optimal response of businesses and households to real economic disturbances to technology. These theories are based upon the market-clearing assumption that prices rapidly adjust to demand and supply conditions. Kydland and Prescott (1982) and Long and Plosser (1983) demonstrated that such an approach could explain important facts regarding U.S. business cycles. Using a standard model of economic growth with empirically plausible shocks to aggregate productivity, or technology shocks, their artificial economies generated business cycles remarkably similar to the actual economy.

While successful at replicating some key business cycle features, one of the primary weaknesses of standard RBC models is their inability to account for some important aspects of U.S. labor market fluctuations. For example, the standard framework is unable to generate sufficient volatility of hours worked, relative to output and average labor productivity. It vastly overstates the contemporaneous correlation between hours and productivity, and it cannot account for the feature that labor productivity tends to lead hours worked over the business cycle. As a result, researchers in the past decade have focused on modifying the RBC framework to address these shortcomings.[1] One example pursued by Hansen (1985) is to treat labor supply as an indivisible decision (a decision to work or not to work), and hence, introduce equilibrium unemployment. Such an approach alters the individual trade-off between work and leisure over time, which makes labor supply more responsive to changes in the real-wage rate. Another direction is to incorporate additional shocks to the economy, such as changes in government spending (Christiano and Eichenbaum, 1992) or shocks to a home production technology (Benhabib, Rogerson and Wright, 1991). This not only makes labor supply more variable over time but lowers the correlation between hours worked and real wages. Finally, time lags between when a firm decides to hire labor or buy capital, and when those inputs become productive, could dampen the contemporaneous response of labor to a technology shock and, therefore, cause productivity to lead hours over the business cycle.[2]

This article will first summarize facts about U.S. business cycles and evaluate how a basic RBC model compares with these facts. Second, it will look at how a RBC model with indivisible labor supply is constructed and analyze its predictions for the labor market. Finally, it will develop a simple framework that demonstrates how a more realistic treatment of unemployment and incomplete risk sharing in an RBC

[1] See Hansen and Wright (1992) and Kydland (1995) for a survey of this literature.

[2] Merz (1995) introduces such time delays in the form of costly search in the labor market while Christiano and Todd (1996) considers a time-to-plan investment process.

Table 1

Relative Volatilities

		Expenditures		Labor Market		
	σ_Y	σ_C/σ_Y	σ_I/σ_Y	σ_H/σ_Y	σ_{PR}/σ_Y	σ_H/σ_{PR}
U.S. Data*	0.0179	0.51	3.14	0.79	0.46	1.72
RBC Model	0.0130	0.32	3.12	0.51	0.51	0.95
CRS Model	0.0173	0.30	3.21	0.76	0.29	2.63
ICRS-1 Model	0.0171	0.31	3.18	0.75	0.30	2.49
ICRS-2 Model	0.0157	0.36	3.10	0.73	0.38	1.90

Table 2

Dynamic Correlation of Output and Hours

	Corr(Y_t,H_{t+j})						
j =	-3	-2	-1	0	1	2	3
U.S. Data*	.30	.53	.76	.90	.88	.74	.58
RBC Model	.34	.51	.72	.98	.63	.35	.14
CRS Model	.33	.50	.72	.98	.62	.34	.14
ICRS-1 Model	.33	.50	.72	.98	.63	.35	.14
ICRS-2 Model	.31	.51	.74	.95	.88	.52	.24

*U.S. data uses chain-weighted logged and HP filtered quarterly time series, 1964:1 – 1994:4, constructed by Pakko (1997). Y = real GDP, C = consumption of nondurables and services, I = fixed nonresidential + consumer durables, H = total hours worked, PR = Y/H = average labor productivity.

model may provide an alternative approach to better account for these U.S. labor market facts. In particular, building upon the RBC model with indivisible labor, our framework looks at the situation where the risk of being unemployed cannot be completely shared across all individuals (unemployment insurance is incomplete).

U.S. BUSINESS CYCLES AND SOME LABOR MARKET FACTS

Figures 1-3 and the first rows of Tables 1-4 document some important U.S. business cycle properties based upon quarterly time-series data. The data are logged and detrended (using the Hodrick and Prescott filter, 1980) so that business cycles are measured as deviations of macro variables around this trend. Real GDP is denoted by Y, the expenditure aggregates are consumption (C) and gross private domestic investment (I), and the labor market variables are total hours worked (H) and average labor productivity ($PR \equiv Y/H$). Table 1 summarizes the relative volatility of these aggregates and shows the well-known fact that while consumption is about half as volatile as income ($\sigma_C/\sigma_Y = 0.51$), total business and residential investment fluctuates about three times as much as income ($\sigma_I/\sigma_Y = 3.14$). In terms of the labor market, Table 1 indicates that hours fluctuate almost as much as output ($\sigma_H/\sigma_Y = 0.79$), labor productivity is about half as volatile ($\sigma_{PR}/\sigma_Y = 0.46$), and hours fluctuate more than one and a half times as much as productivity ($\sigma_H/\sigma_{PR} = 1.72$).

Table 3

Dynamic Correlation of Output and Productivity

	$Corr(Y_t,PR_{t+j})$						
j=	-3	-2	-1	0	1	2	3
U.S. Data*	.43	.51	.56	.61	.37	.19	.01
RBC Model	.17	.38	.64	.98	.74	.54	.37
CRS Model	.01	.23	.51	.87	.75	.64	.52
ICRS-1 Model	.03	.24	.52	.88	.75	.63	.51
ICRS-2 Model	.18	.41	.72	.81	.46	.40	.32

Table 4

Dynamic Correlation of Hours and Productivity

	$Corr(H_t,PR_{t+j})$						
j =	-3	-2	-1	0	1	2	3
U.S. Data*	.47	.45	.37	.22	.13	.01	-.10
RBC Model	.03	.24	.54	.93	.73	.56	.41
CRS Model	-.14	.06	.36	.76	.68	.60	.52
ICRS-1 Model	-.13	.08	.38	.78	.69	.60	.51
ICRS-2 Model	.11	.39	.77	.59	.41	.37	.31

The first rows of Tables 2-4 contain the dynamic correlation of our selected labor market variables with three-quarter lags and leads. It highlights four important features. First, Figure 1 and Table 2 show that total hours are highly procyclical [$Corr(Y_t,H_t) = 0.90$]. Additionally, Table 3 indicates that it is more procyclical than productivity [$Corr(Y_t,PR_t) = 0.61$]. Second, Table 3 shows that while the correlation between output and productivity peaks contemporaneously, it is very close to the one-and two-period lagged correlations. Along with Figure 2, this suggests that productivity may lead the cycle weakly.[3] Third, the contemporaneous correlation between hours and labor productivity is small [$Corr(H_t,PR_t) = 0.22$]. Fourth, Table 4 and Figure 3 show very clearly that productivity leads hours over the cycle [$Corr(H_t,PR_t) < Corr(H_t,PR_{t-1}) < Corr(H_t,PR_{t-2})$]. These four features suggest that labor productivity is an important indicator of future economic activity.

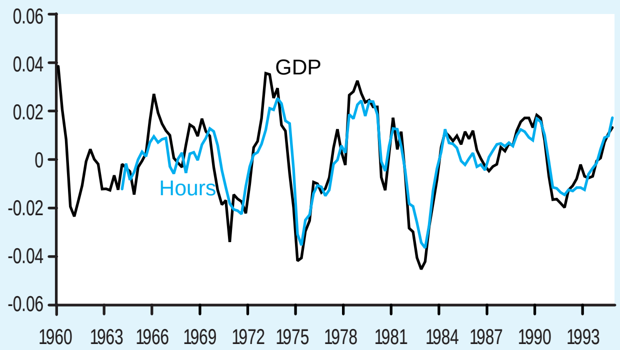
These U.S. summary statistics given by the first rows of Tables 1-4 will be the benchmark with which we evaluate the performance of market-clearing RBC models. In particular, the article will first evaluate how the basic RBC model, given by the second rows of the tables, compares to these U.S. labor market facts. Next, we analyze the indivisible labor model with complete risk-sharing (CRS) and summarize these results in rows three of Tables 1-4. Finally, the paper builds upon this CRS model of indivisible labor by considering the more general case of incomplete risk sharing (IRS) between employed and unemployed individuals. Summary statistics for two versions of the IRS model are presented in the fourth and fifth rows of the tables.

[3] Others, e.g., Kydland (1995), using the establishment survey of hours worked, have found this leading role of productivity over the cycle to be more prominent than that indicated by this table.

Figure 1

Real GDP and Hours*

H-P Deviations from the Trend

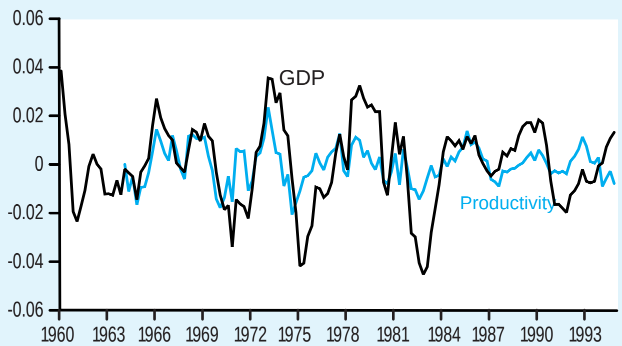


* Output is 1960:1-1994:
Hours is 1964:1-1994:4

Figure 2

Real GDP and Productivity*

H-P Deviations from the Trend



* Output is 1960:1-1994:4
Productivity is 1964:1-1994:4

A BASIC RBC MODEL AND THE FACTS

In a prototypical RBC framework, households behave as if they live forever. They care about current and expected-future consumption as well as current and expected-future leisure. The typical form of preferences adopted in the literature is a time-separable utility function where individuals discount the future:

$$(1)\quad u(c_0,l_0)+\beta u(c_1,l_1)+\beta^2 u(c_2,l_2) + \ldots = \sum_{t=0}^{\infty} \beta^t u(c_t,l_t),$$

where c_t and l_t are consumption and leisure, respectively, at date t, utility is increasing in c and l but also exhibiting diminishing marginal utility and $\beta < 1$ is the time discount factor.

Households earn income at each date by working $h_t = 1\text{-}l_t$ units at a wage rate w_t and renting capital k_t to firms at a rental rate r_t. At each date they spend their income buying goods for consumption and investment, I_t. This leads to the following flow-budget constraint that equates income to expenditures at date t:

$$(2)\quad w_t h_t + r_t k_t = c_t + I_t.$$

Gross investment is defined as new capital goods available at date t+1 less the undepreciated existing capital stock:

$$(3)\quad I_t = k_{t+1} - (1-\delta)k_t,$$

where $\delta < 1$ is the capital depreciation rate. Households maximize expected lifetime utility in equation 1 by choosing c_t, I_t, and l_t, subject to the budget constraint given by equation 2, and taking as given the market wage and capital rental rates.

Firms in this economy demand labor, h_t^d, and capital, k_t^d, to produce output y_t using a Cobb-Douglas production technology given by

$$(4)\quad y_t = A_t F(k_t^d, h_t^d) = A_t k_t^{\alpha} h_t^{1-\alpha},$$

where output is increasing in capital and labor inputs and exhibits diminishing marginal returns in each, and A_t is a productivity shock to this technology. The random process for these productivity shocks is given by $A_t = exp(z_t)$ where $z_{t+1} = \rho z_t + \varepsilon_{t+1}$, ε_t is a serially uncorrelated disturbance with zero mean and constant variance σ_ε^2 and $\rho < 1$ measures the degree of persistence of the shock.

Capital that is accumulated in the

current period is not productive until the following period. Firms maximize profits and will demand labor and capital goods until the wage rate is equated to the marginal product of labor and the rental rate is equated to the marginal product of capital. The assumption of market-clearing ensures that factor prices will adjust to equate the demand and supply of labor, capital, and goods (i.e., $h_t = h_t^d$, $k_t = k_t^d$, and $y_t = c_t + I_t$).

A temporary unanticipated positive shock to A_t creates substitution effects on household behavior along two dimensions. First, the increase in the marginal product of capital provides an incentive to increase investment and intertemporally substitutes current for future consumption. Secondly, the productivity shock raises the marginal product of labor. Households respond to this by substituting leisure for current and future consumption. The overall impact will be a higher equilibrium rental rate, real wage, greater consumption, investment, work effort, and output during the period of the shock. Productivity disturbances are sometimes called the impulse to the business cycle, while the investment process is the mechanism that propagates these shocks over time.[4]

The model is then calibrated by solving it numerically, assigning parameter values, and simulating it over time (under the assumption that individuals have rational expectations regarding future economic variables).[5] Productivity shocks to technology are assumed to be temporary, but also persistent. The outcome is an artificial time series of economic aggregates that can be compared to the facts about U.S. business fluctuations.[6]

The second rows of Tables 1-4 give the predictions of the standard RBC model that can be directly compared to the data displayed in the first rows. Several predictions of the model do quite well. First, the volatility of consumption is significantly less than that of output while investment is substantially more volatile than output. Intuitively, because individuals are forward looking, they desire to spread consumption over time as dictated by the permanent income hypothesis. Secondly, Table 2 shows that hours are strongly procyclical (even a bit more than the data indicate).

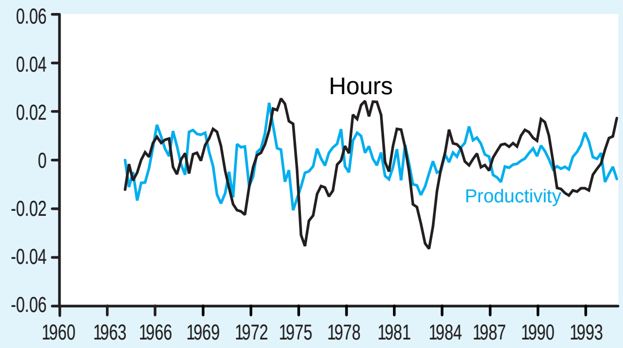
It also is clear from these tables that the major difficulties of the model rest in the labor market. First, the model cannot explain why hours are so volatile (σ_H/σ_Y is 0.51 in the model and 0.79 in the data). Second, the model overstates the procyclical nature of average labor productivity ($Corr(Y_t,PR_t)$ is 0.98 in the model and 0.61 in the data) and says that productivity is strongly contemporaneous with output while the data say that it is only weakly contemporaneous. Third, hours are more volatile than productivity in the data but less volatile in the model (σ_H/σ_{PR} = 0.95 in the model and 1.72 in the data). Fourth, the model vastly overstates the correlation between current hours and productivity (0.93 in the model and 0.22 in the data) and it is unable to explain why productivity leads hours over the cycle (the data show hours to be the most correlated with three-quarters lagged productivity).

Why does the standard RBC model have so much trouble explaining these labor market facts? The answer lies in Figure 4. Productivity shocks, which alter the marginal product of capital, can be viewed as shifts in labor demand along an upward sloping labor supply curve. In particular,

Figure 3

Hours and Productivity*

H-P Deviations from the Trend



* Hours is 1964:1-1994:4
Productivity is 1964:1-1994:4

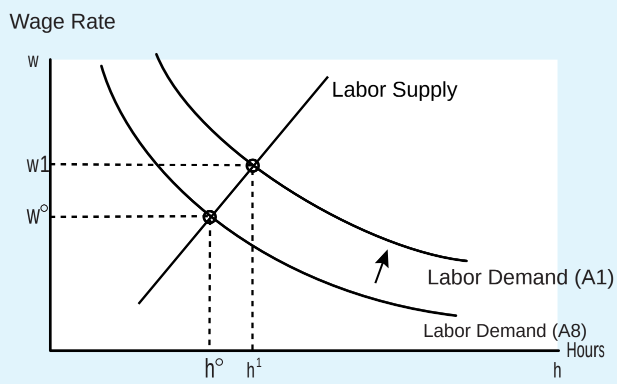
[4] It has been argued, however, that this propagation mechanism is weak because persistence in the technology shock itself is essential to generate a realistic amount of persistence in real output growth.

[5] We use log utility and parameters that are standard to the literature: $u(c,1\text{-}h) = ln(c) + Aln(1\text{-}h)$, $A = 2$, $\alpha = 0.36$, $\beta = 0.99$, $\delta = 0.025$, $\rho = 0.95$, and $\sigma_\varepsilon = 0.00721$.

[6] For more information, readers are directed to a detailed description of the process of solving, calibrating, and simulating RBC models contained in an article for this *Review* by Ritter (1995).

Figure 4

The Labor Market in a RBC Model
($A^{\circ} < A^{1}$)



random chance of being unemployed. The model assumes that firms offer labor contracts that are traded competitively. These contracts provide for unemployment insurance by specifying a guaranteed income flow to each individual worker, regardless of whether that worker is employed or unemployed. This income agreed upon by workers and firms, however, is contingent upon the probability, chosen by the worker, of being employed or unemployed in the current period. Such an environment will be equivalent to one where individuals insure each other against the random outcome of being unemployed; that is, the market for unemployment insurance provides a means to attain *risk sharing*.[9]

Hansen (1985) formalizes such an approach by considering the case where all individuals are identical in terms of skills and productivity, but each faces a random chance in each period of being employed with probability n_t and working L hours or unemployed with probability $1\text{-}n_t$, and working zero hours (i.e., there is an employment lottery). At the beginning of each period, individuals choose n_t to maximize the average of utility they receive if they should be employed or unemployed, weighted by their respective probabilities:

$$(5)\quad \sum_{t=0}^{\infty} \beta^t \left\{ n_t u(c_{1t}, 1 - L) + (1 - n_t) u(c_{2t}, 1) \right\},$$

where c_{1t} and c_{2t} are the individual's consumption choices contingent upon the realization of working and not working, respectively.

Risk sharing is captured by a budget constraint that equates an individual's expected income flow to his expected expenditures in the current

$$(6)\quad w_t n_t L \;+\; (1 - n_t)(0) + r_t k_t \\ = n_t c_{1t} + (1 - n_t) c_{2t} + I_t .$$

The left-hand side of equation 6 is the sum of expected labor income over individual employment status and household rental income; the right-hand side is expected

using model parameters values based upon actual empirical evidence leads to a small intertemporal elasticity of substitution between consumption and leisure, and hence, a small labor supply elasticity (i.e., the labor supply curve is rather steep).[7] As a result, we see:

- Equilibrium hours will not be very responsive.
- Real wages, and hence marginal and average labor productivity, will change by more than hours.
- Technology shocks, which shift labor demand along labor supply, cause real wages and productivity to be almost perfectly correlated *and* contemporaneous with changes in output.

INDIVISIBLE LABOR IN A RBC MODEL

An important innovation to the real business cycle literature—aimed at resolving some of the inconsistencies between the basic model and the data—is to assume that labor supply is *indivisible* so that individuals are either working or not working, i.e., employed or unemployed.[8] In particular, individuals each face a

[7] The labor-supply elasticity required for the model to generate sufficient hours to output volatility is close to two while empirical estimates suggest it is significantly less than one.

[8] This approach addresses the observation that about two-thirds of variations in hours worked come from individuals moving into and out of unemployment with only one-third from variations in hours when employed.

[9] Introducing an all-or-nothing employment decision will imply that the competitive structure of the economy may not correspond with a Pareto efficient equilibrium, i.e., an allocation where no one can be made better off without others being made worse off. Technically, allowing individuals to choose the probability of unemployment, and having a lottery to determine who will actually be unemployed is necessary to circumvent the problem of *non-convexities* in the labor-supply decision. (For more details the reader is directed to Hansen [1985], pp 315-16.)

expenditures on consumption over the employment lottery and household investment.[10] To maximize utility, subject to the budget constraint, individuals simply choose employment probability n_t, consumption plans c_{1t} and c_{2t} (which are contingent upon the outcome of the employment lottery), and investment. Firms in this economy own production technology in equation 4 and demand labor and capital in exactly the same manner as in the basic model. Since each representative firm employs many workers, aggregate labor supply is given by $n_t L$ hours and a labor market equilibrium occurs when $n_t L = h_t^d$.

This formulation of the model embodies the idea of complete risk-sharing (CRS). If it is costless to set up the insurance market for unemployment, and utility is separable in consumption and leisure, then the most beneficial arrangement is to provide for complete unemployment insurance. Such a situation entails that individuals receive the same income and consume identical amounts regardless of their employment status. Since this (costless) pooling of incomes implies that individuals would like to insure each other perfectly against unemployment and each is equally likely to be unemployed, the consumptions of employed and unemployed individuals are equalized, i.e., $c_{1t} = c_{2t}$ for all t.

Figures 5-7 show the impulse response plots of how selected variables in this CRS model respond to a one-period, one-standard deviation positive shock to A_t which persists over several quarters. The shock occurs in period 10 and the vertical axes of Figures 5-7 measure the percent deviation from steady-state values. All variables eventually converge back to their corresponding steady-state values following the one-time shock. Figure 5 indicates that the technology shock raises both employed and unemployed consumption by the same amount above their respective long-run values. Figure 6 shows a boom in investment expenditures in the period of the shock. As Figure 7 indicates, the responses of both output and hours worked are greatest in the period of the shock, while the surge in productivity gradually falls back to steady state. Thus,

Figure 5

Consumption of Employed and Unemployed-CRS Are Identical

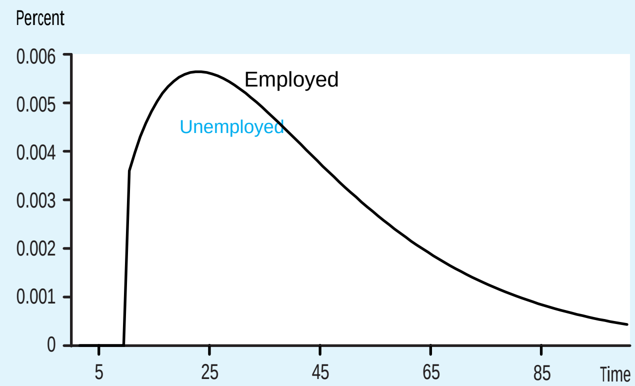
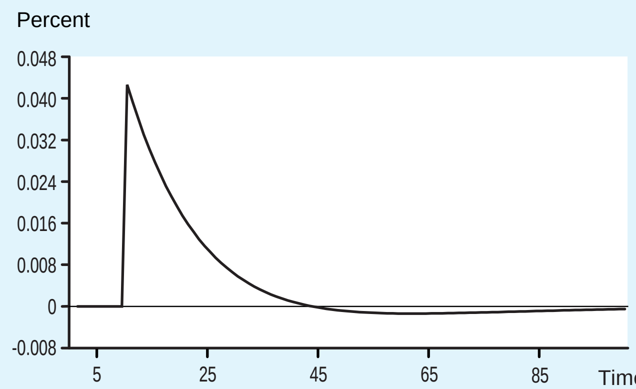


Figure 6

Investment-CRS



productivity certainly does not lead output over the business cycle and its correlation with hours worked is strongly positive.

These cyclical properties are quantified in the third rows of Tables 1-4.[11] As Table 1 shows, $\sigma_H/\sigma_Y = 0.76$. This means that the model does succeed in increasing the volatility of hours worked to a level very close to the data. It also explains why hours fluctuates more than productivity. In fact, the statistic $\sigma_H/\sigma_{PR} = 2.63$ is now too high, rather than too low, relative to the data. Intuitively, because an individual's labor supply is all or nothing at all, the aggregate labor supply elasticity can be much larger than the elasticity at the indi-

[10] Since there are a large number of households, the budget constraint (equation 6) also says that aggregate income must be equal to aggregate expenditures (i.e., it also corresponds to an aggregate resource constraint).

[11] To be comparable to Hansen (1985), we use $L = 0.53$; otherwise, the utility and production function as well as parameter values are identical to that in the standard model above.

Figure 7

Output, Hours, and Productivity

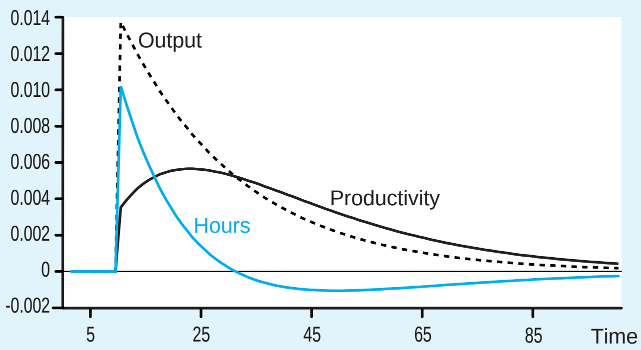
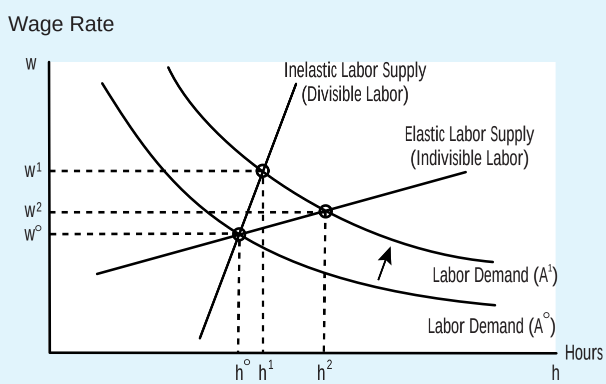


Figure 8

Labor Market (CRS)
($A^{\circ} < A^{1}$)



vidual level.[12] Figure 8 illustrates these labor market effects of a shock to technology with a larger aggregate labor supply elasticity. Finally, Table 4 indicates that although the correlation between hours and productivity is somewhat lower in this model than in the standard RBC model ($Corr(H_t, PR_t)$ = 0.76), it is still significantly larger than the correlation in the U.S. data. The strongest correlation between these two series is contemporaneous, rather than one in which productivity leads hours.

In the following section, we will build upon the RBC model with indivisible labor. In particular, we will suggest how a more realistic treatment of the income constraints that unemployed individuals face—and the notion of incomplete risk sharing—can help with the model's labor market predictions.

UNEMPLOYMENT AND INCOMPLETE RISK SHARING

In the indivisible labor model with complete risk sharing, individuals insure each other perfectly against variations in income due to unemployment. Such a frictionless market, however, also rules out potentially important liquidity constraints that unemployed individuals may face, and hence distorts how labor-supply decisions respond to aggregate shocks. This section provides an example of how incomplete risk sharing may improve upon the model's labor market predictions by considering the more natural case where the unemployed do not have direct access to current labor income.

In our example, the unemployment insurance market of the typical indivisible labor model is replaced with a simple one-period loan market, which permits borrowing and lending between individuals. The major source of friction in this loan market is that individuals make deposits, d_t, *before* the uncertainty about the state of the economy, i.e., the technology shock, A_t, is resolved. For example, there may be broker's fees, shoe leather, or other fixed costs of continuously adjusting these deposits once the initial decision is made.[13] Also, there is a resource cost of participating in this loan market, *s*, which is proportional to the size of d_t. This is meant to capture an implicit opportunity cost of making deposits relative to an outside alternative. This cost is rebated as a lump-sum transfer to households (which own the intermediaries) at the end of the period. Finally, individuals face a competitive market interest rate, R_t, on both deposits and loans.

Once the state of the economy is realized, individuals choose an employment probability. Then an employment lottery randomly assigns individuals to be employed or unemployed. While all individuals

[12] This partially addresses the criticism that RBC models require a large individual labor supply elasticity, but the required elasticity is still above one. Kydland and Prescott (1991) consider the case where individuals can vary both employment choice and hours worked. With fluctuations in hours coming from both margins, they arrive at a much more plausible figure for the relative volatility of hours to productivity.

[13] See Lucas (1990) and Fuerst (1992).

have equal access to rental income, unemployed individuals do not work and have no direct access to labor income. They are constrained to consume from their rental income and funds borrowed from the loan market, b_{2t}. Employed individuals, on the other hand, can consume and purchase capital goods from their rental and labor income as well as any additional funds they decide to borrow from the financial market, denoted as b_{1t}. We can write the unemployment consumption constraint as

$$(7) \qquad c_{2t} \le r_t k_t - d_t + b_{2t},$$

which takes into account that the income that individuals have available is net of their initial deposit decision. In place of equation 6, the average or aggregate budget constraint that allows individuals to pool their resources together, and hence share risk, is now given by

$$(8) \qquad \begin{aligned} &n_t c_{1t} + (1-n_t) c_{2t} + I_t + R_t \\ &\times \left[n_t b_{1t} + (1-n_t) b_{2t} \right] + s d_t \\ &= w_t n_t L + r_t k_t + R_t d_t + \Pi_t. \end{aligned}$$

The left-hand side of equation 8 is total expenditures by employed and unemployed individuals on consumption, interest payments on loans, household investment, and the implicit costs of participating in the loan market. The right-hand side is total income from wages earned by the employed, household rental income, interest on deposits, and lump-sum transfers of the financial market profits, $\Pi_t = sd_t$.[14] Since interest is paid on these loans at the end of the period, and no assets or IOUs are traded across periods, this is an intratemporal rather than intertemporal loan market. It simply permits individuals to smooth consumption against realizations of their employment status. Thus, while risk sharing guarantees that individuals are identical at the beginning of every period, or *ex ante*, an unanticipated aggregate shock causes their consumption decisions to differ based upon the random realization of their employment status, and hence they may not be identical *ex post*.

Figure 9

Deposits-CRS

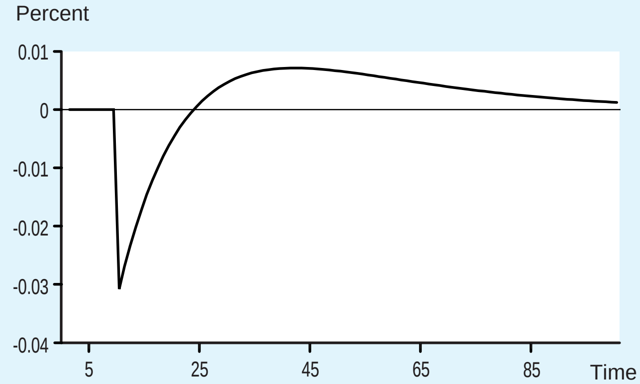
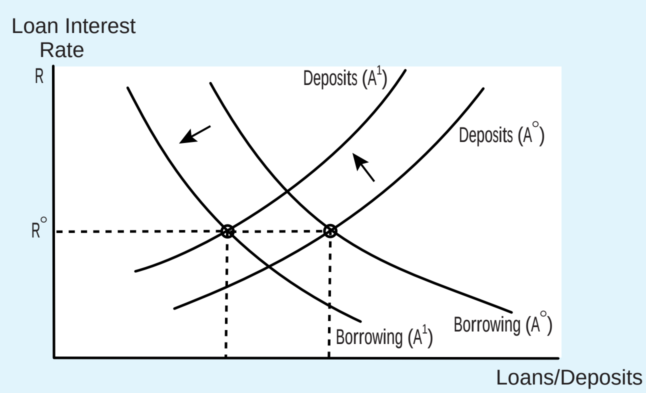


Figure 10

Loan Market Equilibrium in ICRS-1 Model $(A^\circ < A^1)$



Individuals take wages, rental rate, and loan market rates as given. They choose deposits (before the technology shock), an employment probability, consumption contingent on the realization of employment, and investment to maximize lifetime utility (equation 5), subject to budget constraints given in equations 7 and 8. Firms in this economy own the production technology (equation 4) and demand labor and capital in exactly the same manner as in the previous section. As in the CRS model, labor market equilibrium occurs when $n_t L = h_t^d$. There is an additional market-clearing condition

[14] In an economy with many identical intermediaries, households take these profits as a lump-sum quantity when they make their decisions. That is, Π_t is taken as given when households choose deposit, consumption, and labor supply decisions and $sd_t = \Pi_t$ holds *ex post*.

Figure 11

Consumption of Employed and Unemployed - ICRS-2

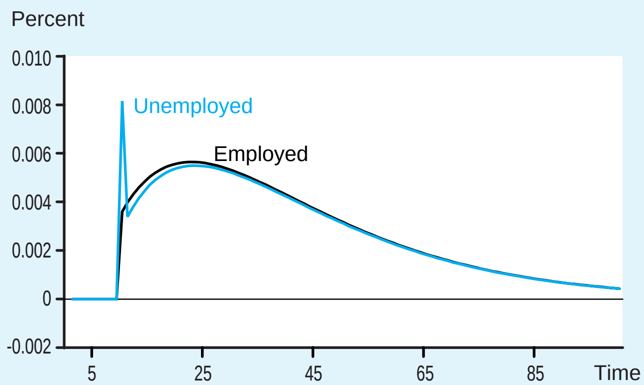


Figure 12

Investment - ICRS-2

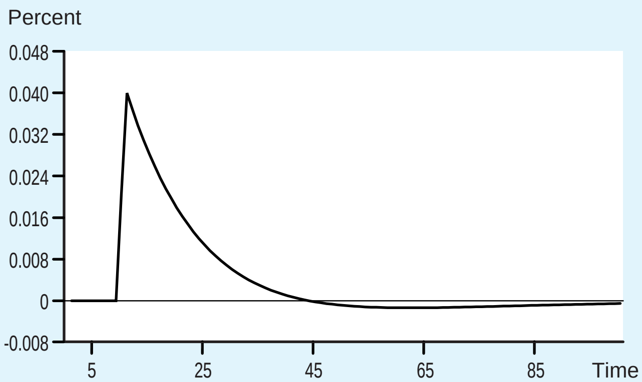
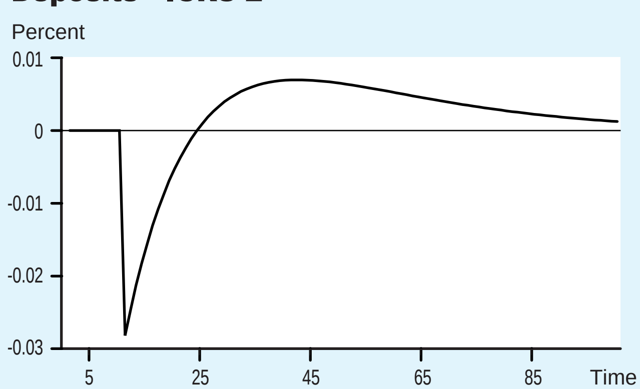


Figure 13

Deposits - ICRS-2



for the loan market that equates total financial market deposits to loans, and is given by $d_t = n_t b_{1t} + (1-n_t)b_{2t}$. In equilibrium, as long as $R_t > 0$, it will never be optimal for employed individuals to borrow in order to finance their consumption so that $b_{1t} = 0$. We will now summarize the major results of this set up, leaving the technical aspects of solving the model to the appendix.

First, consider the situation where there is no uncertainty about the aggregate state of productivity when the deposit decision is made (d_t is chosen after A_t is known), and there are no loan market participation costs ($s = 0$). This is the special case where risk sharing is complete both across and within periods so that $c_{1t} = c_{2t}$ for all dates t, and the model is identical to the CRS model of Hansen (1985) considered above. The loan market simply is acting as a transfer mechanism between employed and unemployed individuals and hence provides complete insurance against aggregate shocks to production and income. Figure 9 gives the impulse response plot of deposits to a positive shock to technology. Since the shock lowers unemployment, and there is no uncertainty about the shock when deposit decisions are made, supply and demand for these loans fall in equal amounts while the loan market interest rate remains constant (see Figure 10).

Next, consider the case where there are small but positive costs for participating in this loan market ($s > 0$), but still no uncertainty about the economy when deposits are made. In this case, the consumption of unemployed individuals now is lower than that of the employed, $c_{2t} < c_{1t}$, because it is costly for the loan market to transfer income across individuals. We call this form of incomplete risk sharing the ICRS-1 model. The impulse response plots are practically identical to those contained in Figures 5-7 (and omitted). The fourth rows of Tables 1-4 show that the cyclical properties of ICRS-1 indeed are very similar to the CRS model. Intuitively, as the state of the economy is observed when borrowing and lending decisions are made, risk is still shared efficiently (but not completely) across individuals and the costs of participating in the loan market make little difference to the dynamic effects of technology shocks. Hence, the labor market effects of ICRS-1 also can be illustrated by Figure 8.

Finally, we consider the form of incomplete risk sharing where there is uncertainty about the aggregate state of the economy when deposit decisions are made (d_t chosen *before* A_t is realized). Impulse responses to a one standard deviation positive-technology shock for this ICRS-2 model are shown in Figures 11-15. While the consumption of both employed and unemployed increases in Figure 11, unemployed consumption deviates from its long-run value by a greater percentage during the period of the shock. The reasoning is that loan market equilibrium requires $d_t = b_{2t}(l - n)$. Intuitively, since the supply of loanable funds, d_t, is fixed and cannot react in the period of the shock, the reduction of unemployment ($1-n_t$) reduces the total demand for loans by the unemployed and the loan market interest rate (Figures 14 and 16). Thus, the cost of financing consumption loans for each unemployed individual decreases and borrowing per unemployed individual, b_{2t}, rises. This has the effect of dampening the initial increase in hours and investment, as shown in Figures 12 and 15. As a result, productivity surges in the period of the shock while investment, hours, and output continue to rise during the period following the shock. Interestingly, the fact that output rises for two periods after the shock suggests that incomplete risk sharing strengthens a propagation mechanism, which is inherently weak in a standard RBC framework.

These features are captured more precisely in the model's summary statistics in the fifth rows of Tables 1-4. Table 1 indicates that the relative volatilities of each variable to output change very little when compared to the complete risk sharing case; however, the volatility of hours to productivity is now much lower (1.90 rather than 2.63 in CRS) and closer to the data. The dynamic correlations are now able to replicate several important features suggested by the impulse response diagrams. First, Table 4 shows that productivity leads hours with the peak correlation occurring between current hours and one period lagged productivity. Secondly, Table 4 also indicates that the contemporaneous correlation between hours and productivity of 0.59 is significantly lower than that in the CRS model. Third, the contemporaneous correlation between output and productivity in Table 3 is lowered and the output-one period lagged productivity correlation is much stronger and closer to its contemporaneous correlation.

Again, some intuition behind these labor-market predictions can be obtained from a labor-market equilibrium diagram (Figure 17). Consider a *negative* unanticipated shock to technology. Given the inability of aggregate deposits to adjust to this

Figure 14

Loan Market Interest Rate - ICRS-2

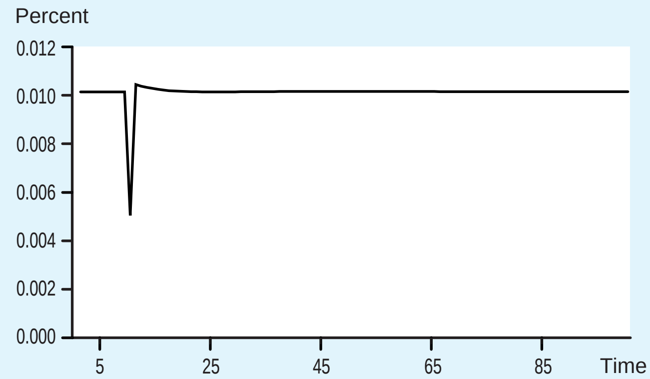


Figure 15

Output, Hours, and Productivity - ICRS-2

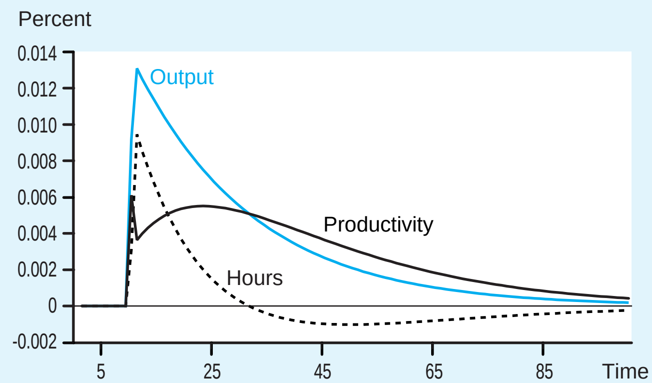
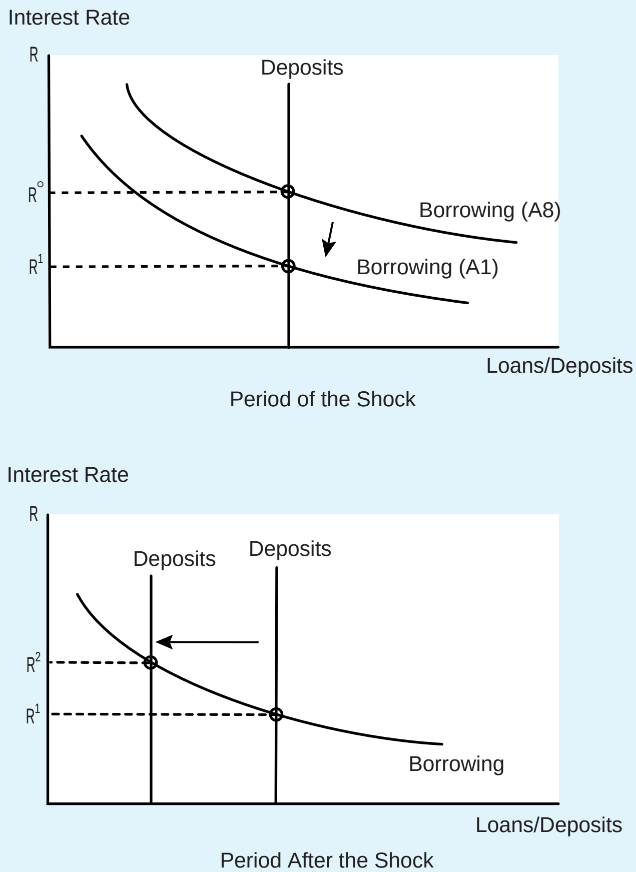


Figure 16

Loan Market Equilibrium in ICRS-2 Model ($A^{\circ} < A'$)



unanticipated shock, the increase in the loan market interest rate diminishes the incentives to be unemployed. In an actual economy, this may correspond to situations where unemployed individuals face tighter liquidity constraints or an increased likelihood of being turned down for loans in a recession.[15] The employment response still leads to a larger labor elasticity compared to the standard RBC model, because of the indivisible labor. But the elasticity is still smaller compared to CRS, because of the incomplete risk sharing. As labor demand shifts backwards, hours will fall by more than wages and productivity, but it will not overstate this feature as in CRS. In the period following the shock, supply to the loan market rises and this increases the incentives to enjoy leisure and finance consumption through loans. Thus, while labor demand begins to return to its original value, labor supply actually shifts backwards and hours and wages move in opposite directions. Consequently, the contemporaneous correlation between productivity and hours falls and equilibrium hours and output may continue to fall after the technology shock. It is this channel of dampening the initial response of labor supply to aggregate shocks that causes changes in productivity to lead changes in hours worked over the business cycle.

[15] The idea that economic downturns may lead to a decrease in net worth and magnify agency costs and credit rationing has been emphasized in the business lending context by Bernanke and Gertler (1989), among others.

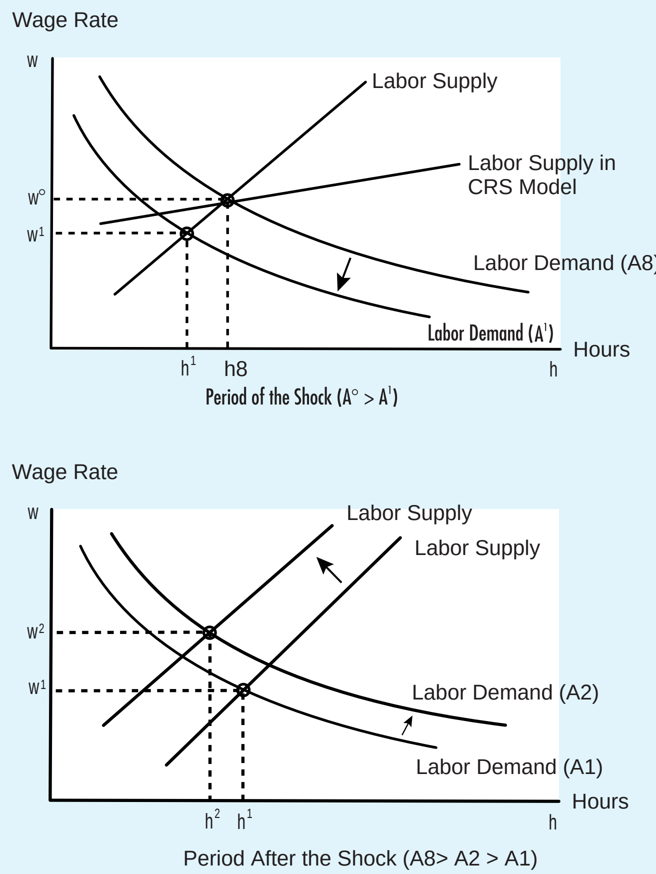
CONCLUSION

Real business cycle theory has demonstrated that a simple neoclassical model of economic growth with supply-side disturbances can have remarkable success in explaining important business cycle facts. This article presents some basic U.S. labor market facts and explains why the labor market predictions of the basic RBC model have been received by many with skepticism. It also shows how the inclusion of indivisible labor and unemployment into an RBC model can improve these labor market predictions. Finally, it suggests that a more explicit treatment of incomplete risk sharing may help resolve some of the model's more problematic labor market predictions. Among them are that productivity tends to lead hours over the cycle, the low hours-productivity contemporaneous correlation, and the high relative volatility of hours worked to productivity.

This paper also draws interesting parallels to the time-to-plan specification of Christiano and Todd (1996)—where capital goods are not productive until several periods after the investment decision is made—and Merz (1995), who incorporates labor market search into RBC models. All of these approaches, including our example of incomplete risk sharing, emphasize features of the economy that dampen the response of production factors to aggregate shocks. They also help in better matching the movement of hours and productivity to output and each other over the business cycle. The main idea behind our example simply is that not permitting unemployed individuals the same access to income and consumption opportunities as those employed significantly affects how aggregate labor supply reacts to uncertain economic shocks. The results in the paper suggest that an explicit treatment of frictions in both the labor and financial markets and their interactions may be a fruitful direction for future research when evaluating the labor market performance of market-clearing business cycle models.

Figure 17

Labor Market with Negative Technology Shock in ICRS-2 Model



REFERENCES

Benhabib, Jess, Richard Rogerson, and Randall Wright. "Homework in Macroeconomics: Household Production and Aggregate Fluctuations," *Journal of Political Economy* (December 1991), pp. 1166-87.

Bernanke, Ben, and Mark Gertler. "Agency Costs, Net Worth, and Business Fluctuations," *American Economic Review* (March 1989), pp. 14-31.

Christiano, Lawrence J., and Martin Eichenbaum. "Current Real Business Cycle Theories and Aggregate Labor Market Fluctuations," *American Economic Review* (June 1992), pp. 430-50.

________ and Richard M. Todd. "Time to Plan and Aggregate Fluctuations," Federal Reserve Bank of Minneapolis, *Quarterly Review* (Winter 1996), pp. 14-27.

Fuerst, Timothy S. "Liquidity, Loadable Funds, and Real Activity," *Journal of Monetary Economics* (February 1992), pp. 3-24.

Hansen, Gary D. "Indivisible Labor and the Business Cycle," *Journal of Monetary Economics* (November 1985), pp. 309-27.

________ and Randall Wright. "The Labor Market in Real Business Cycle Theory," Federal Reserve Bank of Minneapolis *Quarterly Review* (Spring 1992), pp. 2-12.

Hodrick, Robert, and Edward Prescott. "Post-War U.S. Business Cycles: An Empirical Investigation," Working Paper, Carnegie-Mellon University, 1980.

Kydland, Finn E. "Business Cycles and Aggregate Labor Market Fluctuations," in *Frontiers in Business Cycle Research*, T.F. Cooley, ed., Princeton University Press, 1995.

________ and Edward Prescott. "Time to Build and Aggregate Fluctuations," *Econometrica* (November 1982), pp. 1345-70.

________ and ________. "Hours and Employment Variation in Business Cycle Theory," *Economic Theory* (January 1991), pp. 63-81.

Long, John B., and Charles Plosser. "Real Business Cycles," *Journal of Political Economy* (February 1983), pp. 39-69.

Lucas, Robert E., Jr. "Liquidity and Interest Rates," *Journal of Economic Theory* (April 1990), pp. 237-64.

Merz, Monika. "Search in the Labor Market and the Real Business Cycle," *Journal of Monetary Economics* (November 1995), pp. 269-300.

Pakko, Michael R. "The Business Cycle and Chain-Weighted GDP: Has Our Perspective Changed?" this *Review* (September/October 1997), pp. 39-49.

Ritter, Joseph A. "An Outsider's Guide to Real Business Cycle Modeling," this *Review* (March/April 1995), pp. 49-60.

Appendix

This appendix formalizes the solution to the incomplete risk sharing model. The technology shock $A_t = exp(z_t)$ where z_t follows a stationary AR(1) process:

$$\text{(A1)} \qquad z_{t+1} = \rho z_t + \varepsilon_{t+1}$$

and ε_1 is a pure white noise disturbance with zero mean and constant variance σ_ε^2. Given $u(c_t,1_t) = u(c) + V(1 - L)$ where $u(c) = ln(c)$ and $V(1 - L)$ the first-order conditions for $\{c_{1t}, c_{2t}, d_t\, b_{1t}, b_{2b}, n_t, k_{t+1}\}$ associated with maximizing equation 5 subject to equations 7 and 8 are given by:

$$\text{(A2)} \qquad u'(c_{1t}) = \lambda_{1t},$$

$$\text{(A3)} \qquad (1-n_t)u'(c_{2t}) = (1-n_t)\lambda_{1t} + \lambda_{2t},$$

$$\text{(A4)} \qquad E_{t-1}\left\{\lambda_{1t}(R_t - s) - \lambda_{2t}\right\} = 0,$$

$$\text{(A5)} \qquad \lambda_{1t} n_t R_1 b_{1t} = 0,$$

$$\text{(A6)} \qquad \left[\lambda_{2t} - \lambda_{1t}(1-n_t)R_t\right] b_{2t} = 0,$$

$$\text{(A7)} \qquad \begin{aligned} & u(c_{1t}) - uc_{2t} \\ & + \lambda_{1t}\left[c_{2t} - c_{1t} + R_t(b_{2t} - b_{1t}) + w_t L\right] \\ & = V(1) - V(1-L), \textit{ and} \end{aligned}$$

$$\text{(A8)} \ \lambda_{1t} = \beta E_t\left\{\lambda_{1,t+1}(1 + r_{t+1} - \delta) + \lambda_{2t+1^{r}t+1}\right\},$$

where λ_1 and λ_2 are multipliers for the budget constraint given in equation 8 and the unemployed consumption constraint (equation 7). Notice from equations A2 and A3 that $\lambda_2 = (1-n_t)[u'(c_{2t}) - u'(c_{1t})]$. Thus, a necessary and sufficient condition for unemployment consumption constraint in equation 7 to bind is given by $c_{2t} < c_{1t}$. The time t-1 expectations operator in equation A4 indicates that d_1 is chosen before productivity shock z_t is realized. Notice that if $s = 0$, then the model is completely standard with $\lambda_{2t} = 0$ and $c_{2t} = c_{1t}$. From these we can immediately rule out several cases with regard to the borrowing decision of employed and unemployed individuals. It is straightforward to verify that a sufficient condition to rule out $b_{1t} > 0$ is given by $R_t > 0$. The case where $b_{1t} = b_{2t} = 0$ is possible if and only if complete risk sharing can be achieved without use of the loan market; however, this case can be ruled out quantitatively given the steady state consumption and income levels implied by the model parameterization. This leaves us with the most natural case of $b_{1t} = 0$ and $b_{2t} > 0$ Equations A2, A3, and A6 give us $R_t = [u'(c_{2t}) - u'(c_{1t})]/u'(c_{1t})$. Substituting these and the market-clearing conditions into equations A7, A8, and A4 gives

$$\text{(A9)} \qquad \begin{aligned} & u(c_{1t}) - u(c_{2t}) \\ & + u'(c_{1t})\left[c_{2t} - c_{1t} + w_t L\right] \\ & + \left[u'(c_{2t}) - u'(c_{1t})\right]\frac{d_t}{1-n_t} \\ & = V(1) - V(1-L), \end{aligned}$$

$$\text{(A10)} \quad u'(c_{1t}) = \beta E_t \left\{ \begin{aligned} & u'(c_{1,t+1})\left[1 + f_K\left(\begin{matrix} z_{t-1}, k_{t+1}, \\ n_{t+1}L \end{matrix}\right) - \delta\right] \\ & + f_K(z_{t+1}, k_{t+1}, n_{t+1}L)(1-n_{t+1}) \\ & \left[u'(c_{2,t+1}) - u'(c_{1,t+1})\right] \end{aligned} \right\}, \textit{ and}$$

$$\text{(A11)} \qquad E_{t-1}\left\{ \begin{aligned} & n_t\left[u'(c_{2t}) - u'(c_{1t})\right] \\ & -su'(c_{1t}) \end{aligned} \right\} = 0.$$

Equations A9, A10, and A11 give the efficiency condition for n_t, k_{t+1}, and d_t. To obtain some intuition behind these conditions we must first consider the case where d_t is chosen after the productivity shock. If $s = 0$, then $c_{1t} = c_{2t}$, and these conditions collapse to a standard RBC model with indivisible labor. While risk is still shared efficiently for $s > 0$, it is costly to participate in the loan market, and from equation A11, $c_{2t} < c_{1t}$, $R_t > 0$ and the unemployment consumption constraint in equation 7 binds. Quite intuitively, this binding constraint increases the marginal benefit of an additional worker and an additional unit of capital, as captured by the fourth term in equation A9 and the second term in the expectations operator in equation A10. Finally, if d_t is chosen before the productivity shock is revealed, the previous statements hold only in expected value terms because risk sharing will be incomplete. For example, if the productivity shock is unexpectedly high, then the unemployment consumption constraint in equation 7 binds less than expected, thereby implying a lower-than-average marginal benefit to additional workers and capital during the period of the shock. It is this feature that will generate quantitatively different results relative to the complete risk sharing case.

To be comparable to previous real business cycle studies (e.g. Hansen and Wright, 1992) we choose $\alpha = 0.36$, $\beta = 0.99$, $\sigma = 0.025$, $L = 0.53$, $\rho = 0.95$, and $\sigma_\varepsilon = 0.00721$. The transactions cost variable s is chosen to be 0.0058 so that the steady-state loan market interest rate corresponds to the rate of time preference. The models are solved by linearizing Euler equations A8, A9, and A10 about the model's steady state.