Monetary Policy Shocks and Aggregate Supply

By Willem Van Zandweghe

During the past six years of slow economic growth, economists and policymakers have expressed repeated concern that the financial crisis and recession of 2007-09 may have harmed the U.S. economy's productive capacity. Workers' participation in the labor force declined in the recovery, and growth in labor productivity slowed from its historical trend. The disappointing performance of these and other supply-side indicators has led economists to revise down their estimates of the economy's potential output (CBO; Ball; Hall).

A sustained period of weak demand may have caused supply-side damage, eroding the economy's productive capacity through various channels. Many workers may have lost skills due to long spells of unemployment or labor force nonparticipation, and the business sector may have held back on capital formation, business formation, and innovation.

Traditionally, monetary policy is assumed to stabilize economic activity and inflation without affecting the economy's productive capacity—that is, its potential output. However, if weak demand erodes capacity, then monetary policy may be able to expand capacity by stimulating economic activity. Accommodative monetary policy raises demand for goods and services, thus promoting investment and labor market activity and improving the climate for innovation and new business startups. Indeed, recent remarks by policymakers recognize that supply-side damage could be reversible (Yellen; Powell).

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However, as concerns about supply-side damage have only recently gained prominence in monetary policy discussions, there is scant literature on monetary policy's supply-side effects. To help fill this gap, this article examines whether monetary policy has long-lasting effects on labor productivity and potential output.

The empirical analysis suggests that historically, labor productivity temporarily increases following a surprise expansion of monetary policy, with no longer-term effects. This increase can be explained by firms' more intense use of available production factors. As firms cannot operate their production factors above the normal capacity rate indefinitely, surprise deviations of the stance of monetary policy from its systematic behavior do not significantly raise trend labor productivity, which is associated with increases in potential output.

In the current recovery, in which the effective federal funds rate has been constrained by the zero lower bound, the Federal Reserve has turned to unconventional tools to provide additional monetary policy accommodation. These unconventional tools were successful in keeping the level of accommodation aligned with monetary policy's systematic historical behavior. As a result, recent policy surprises have had only a modest influence on labor productivity. However, had the Federal Reserve not employed its unconventional policies, the stance of monetary policy would have been tighter, dampening output and labor productivity. In this way, the additional accommodation provided by unconventional monetary policy tools appears to have boosted output and labor productivity substantially.

Section I shows that various supply-side indicators are positively correlated with the business cycle. Section II provides empirical evidence of the dynamic responses of labor productivity and its key determinants to a monetary policy shock. Section III examines the possible influence of monetary policy actions on labor productivity during the current recovery.

I. Supply-Side Factors in the Business Cycle

Multiple measures of the economy's productive capacity move in tandem with the business cycle. These fluctuations suggest it may be possible for monetary policy to influence the economy's supply side by stimulating economic expansion.

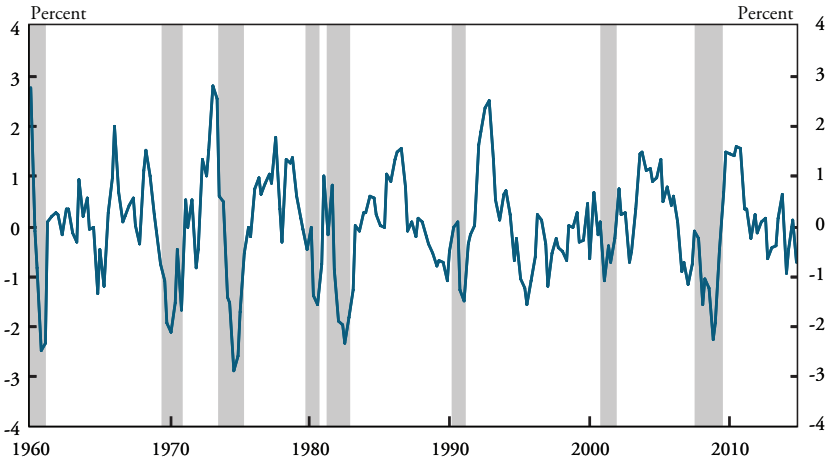
To analyze the business cycle in macroeconomic time series, it is customary to remove low-frequency variation in the data using the time series' statistical trend. While the possible supply-side effects of fluctuations in demand blur the conceptual distinction between trend and cycle, this conventional approach to business cycle analysis remains useful. The business cycle is characterized by the joint movement of many macroeconomic variables. When cyclical output increases, other variables such as hours worked tend to rise; when cyclical output declines, the opposite is typically true. Therefore, cyclical fluctuations in indicators of the economy's productive capacity suggest business cycles can have long-lasting supply-side effects. For example, during an economic upswing, a cyclical rise in research and development spending or new business formation could leave the economy's productive capacity persistently higher.

Labor productivity fluctuates over the business cycle. Chart 1 shows the cyclical component of output per hour, obtained by removing a smoothed trend—the Hodrick-Prescott (HP) filter with a smoothing parameter of 1,600—along with the recession periods defined by the National Bureau of Economic Research (NBER). Labor productivity tends to fall below trend during recessions and rise above trend during expansions. In the expansions of the 1990s and 2000s, labor productivity peaked early on and slowed in the later stages. Likewise, labor productivity surged in the aftermath of the 2007-09 recession but has slowed in recent years.[1] The cyclical nature of labor productivity can be summarized by its correlation with output. Table 1 shows that cyclical labor productivity is positively correlated with cyclical output (a correlation coefficient of 0.38), while the correlation between the growth rates of labor productivity and output is larger (0.67).

While the cyclicality of labor productivity is well established, a less documented idea is that economic downturns could cause lasting supply-side damage by lowering trend labor productivity. Reifschneider, Wascher, and Wilcox show that potential output has declined since the onset of the last recession and attribute the decline largely to lower trend labor productivity.[2] Labor productivity increased at an average annual rate of 1.3 percent in the recovery period from 2009:Q3 to 2014:Q4, below the average growth rate in the pre-recession period from 2003:Q4 to 2007:Q4 (1.8 percent).[3] To assess how a

Chart 1

Cyclical Labor Productivity



Note: Gray bars denote NBER-defined recessions.
Sources: Bureau of Labor Statistics and Haver Analytics.

Table 1

Business Cycle Correlations of Innovation Indicators

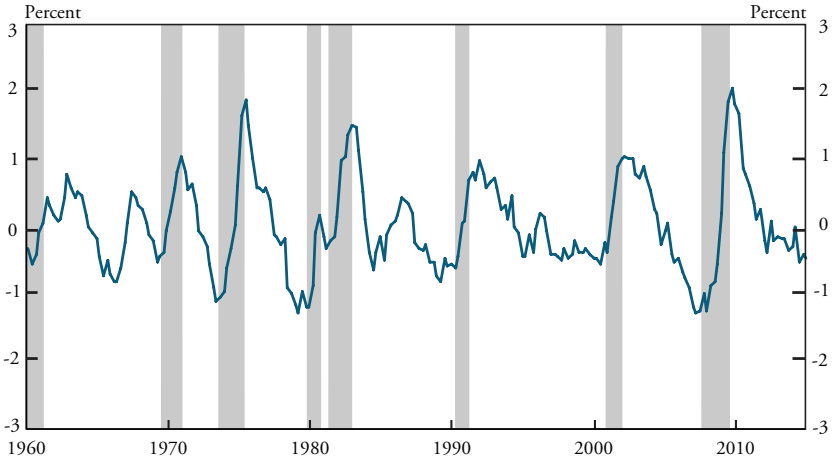
	Labor productivity	Factor inputs per hour	Total factor productivity	R&D investment	Establishment births minus deaths	Net business formation
Cyclical output	0.38	-0.88	0.11	0.47	—	—
Output growth	0.67	-0.64	0.25	0.36	0.55	0.02

Notes: The table reports correlation coefficients of each variable with real output in the business sector, which has been transformed in the same way as the variable: by subtracting the Hodrick-Prescott filter with a smoothing parameter equal to 1,600 from the log level (row 1), or by taking first differences of the log level (row 2). The rate of establishment births minus deaths and net business formation are measures of the rate of change in the number of firms, so the table reports the correlation coefficients of their levels with the growth rate of output. The sample period is 1993:Q2-2012:Q4 for the rate of establishment births minus deaths, 1948:Q1-1994:Q4 for net business formation, and 1960:Q1-2014:Q4 for all other variables.
Sources: Bureau of Economic Analysis, Bureau of Economic Analysis (1996), Bureau of Labor Statistics, Fernald (2014), and Haver Analytics.

recession may affect trend labor productivity, it is useful to first analyze its effect on individual sources of labor productivity. Fernald (2014) identifies three major sources of variations in quarterly labor productivity: available factor inputs per hour worked, the intensity with which firms use available capital and labor, and total factor productivity, a residual component that captures the productivity-enhancing effects of various unmeasured factors.[4] Each of these sources has its own implications for trend labor productivity.

Chart 2

Cyclical Factor Inputs Per Hour



Note: Gray bars denote NBER-defined recessions.
Source: Fernald (2014) and author's calculations.

Factor inputs per hour of work

Labor productivity can shift depending on the supply of capital and labor available per hour worked. For example, subdued investment reduces growth in the capital stock and thus growth in available capital per hour worked, slowing what is called capital deepening. A more skilled workforce, on the other hand, increases the labor input per hour worked, known as labor quality, thus raising labor productivity. Capital deepening and improvements in labor quality are similar insofar as the former changes the available physical capital per hour worked and the latter changes the available human capital per hour worked. As changes in the capital stock (physical or human) are long-lasting, they likely affect trend labor productivity. However, in an economic downturn, factor inputs per hour could increase if hours worked decline sharply and the capital stock or labor quality is slow to adjust. An increase in labor productivity due to a drop in hours worked would not indicate an improvement in trend labor productivity.

Chart 2 shows factor inputs per hour—that is, capital per hour and labor quality—as percent deviations from the HP trend.[5] Factor inputs per hour typically increase during recessions and decline during expansions. Consistent with this pattern, the series of factor inputs per hour

is highly negatively correlated with output (see Table 1). The countercyclical pattern reflects how hours worked fall in recessions and rise in expansions in the face of slowly adjusting capital and labor quality. The pattern indicates that, on their own, fluctuations in available capital and labor quality have little influence on cyclical labor productivity. Therefore, cyclical fluctuations in labor productivity that derive from this source would not necessarily point to supply-side effects.

Factor use

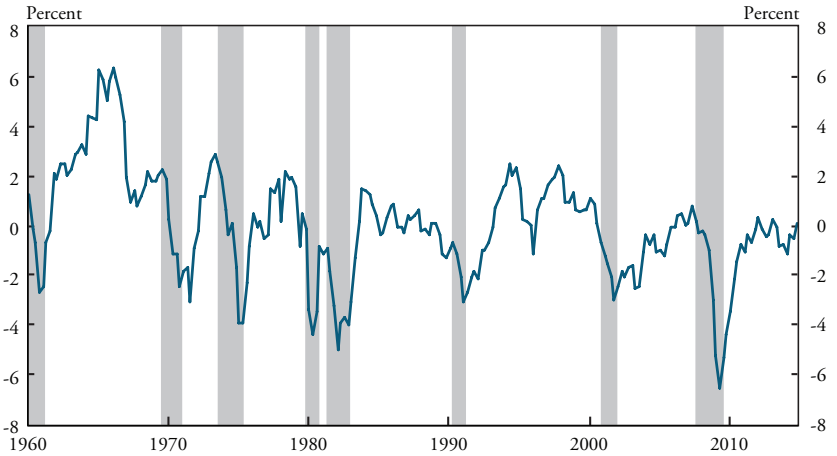
Firms can influence labor productivity in an economic downturn by altering the intensity with which they use available capital and labor. When output demand is low, firms may use their available production factors less intensively. For example, firms can reduce capital utilization by idling machines. Even with this reduced production level, adjustment costs such as hiring and firing costs can encourage firms to "hoard" labor by keeping more workers employed than necessary. In such a scenario, workers' effort falls, and their output declines more than their hours worked, thus reducing the output produced per hour. A decomposition of labor productivity must account for the less intensive use of available production factors to avoid measuring them as lower total factor productivity. However, this source of variation in labor productivity reflects cyclical fluctuations in demand and does not affect trend labor productivity, as firms cannot permanently operate labor and capital above their normal capacity rate. Chart 3 shows that factor use declines during recessions and rises during expansions, consistent with the idea of labor hoarding and a varying workweek of capital.[6]

Total factor productivity

Labor productivity can also shift due to changes in total factor productivity (TFP). Just as labor productivity measures the efficiency of an hour of labor in producing output, TFP measures the efficiency of all measured inputs—hours worked, capital, and labor quality—combined. This measure will depend on the level of available production technologies and the government regulations that apply to them, among other influences. In an economic downturn, for example, innovation may decline as a result of reduced spending on research and development and fewer new business startups, which could be restrained by inadequate

Chart 3

Factor Use



Note: Gray bars denote NBER-defined recessions.
Source: Fernald (2014) and author's calculations.

financing or increased uncertainty about future macroeconomic conditions. Innovation leads to better production technologies, and a temporary decline in innovation could thereby reduce the level of TFP relative to its trend. A persistent decline in TFP could point to flattening trend labor productivity.

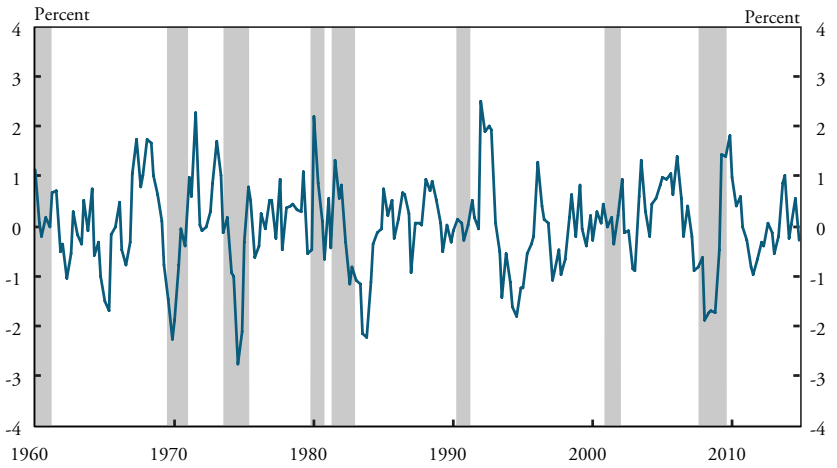
Chart 4 displays the percent deviations of TFP from the HP trend. TFP tends to fall below trend during recessions and rise above trend during expansions. However, the pattern is not quite as pronounced as for labor productivity; for example, the decline in TFP was smaller than the decline in labor productivity during the recessions of 1990-91 and 2001. To the extent variations in TFP reflect the ebb and flow of technological progress, they may suggest cyclical fluctuations in labor productivity have long-lasting, supply-side effects.

Direct innovation indicators

While fluctuations in TFP may reflect changes other than innovation, such as changes in business regulations, more direct measures of innovation also display business cycle fluctuations. Investment in research and development (R&D) factors critically into technological progress. Chart 5 displays the percent deviations of real private

Chart 4

Cyclical Total Factor Productivity



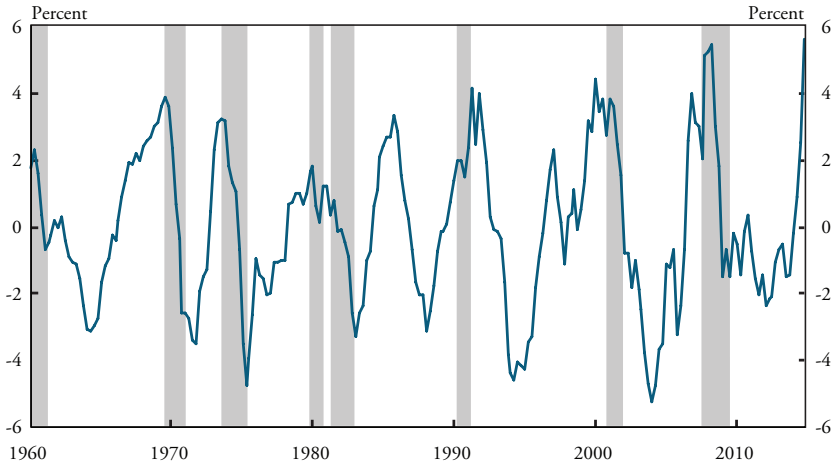
Note: Gray bars denote NBER-defined recessions.
Source: Fernald (2014) and author's calculations.

nonresidential investment in R&D from the HP trend. As with labor productivity, R&D spending typically rises during economic expansions and falls during recessions, though the pattern appears to have shifted over time. R&D spending experienced an additional peak and trough during the recovery of the 1980s. In the last three economic recoveries, investment in R&D continued to fall behind its historical trend for some time after the recession ended.

Another innovation indicator is the entry and exit of firms, which may reflect the creative destruction associated with technological progress. Business startups can bring new products to market and innovate production processes; firms with outdated products and processes are more likely to close. Chart 6 shows changes in two measures of firm entry and exit. Net business formation is an index that runs from 1954 through 1994, and the rate of births minus deaths of private sector establishments is available from 1993 onward.[7] Both series display marked declines during recessions, indicating fewer new firms enter and more firms exit than in expansions. A decline in new firm entries likely hurts aggregate labor productivity, but a rise in firm exits may, in fact, raise labor productivity by cleansing inefficient firms from the market. Which effect dominates has been contentious in past

Chart 5

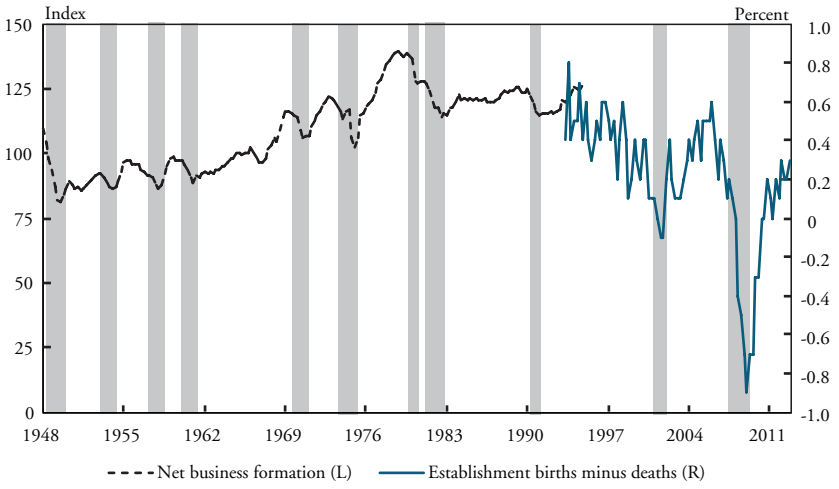
Cyclical Investment in Research and Development



Note: Gray bars denote NBER-defined recessions.
Sources: Bureau of Economic Analysis and Haver Analytics.

Chart 6

Rate of Establishment Births Minus Deaths and Net Business Formation



Note: Gray bars denote NBER-defined recessions.
Sources: Bureau of Economic Analysis (1996), Bureau of Labor Statistics, and Haver Analytics.

recessions; however, evidence for the 2007-09 recession points more clearly to a slowing of reallocation due to fewer firm entries.[8]

TFP and most other innovation indicators are positively correlated with output (see Table 1). TFP displays a mild positive correlation with output, even after removing the cyclical component of factor use. In particular, the growth rate of TFP has a correlation coefficient of 0.25, suggesting a cyclical decline in output growth could be associated with a lasting decline in the level of TFP. Likewise, R&D investment and the rate of establishment births minus deaths are positively correlated with output, although net business formation, an older measure, is effectively uncorrelated with output growth. Consistent with these findings, Comin and Gertler show R&D expenditures are positively correlated with output, and the relative price of investment is negatively correlated with output. Alexopoulos constructs measures of technology from book titles in the field of technology and shows their lagged values are positively correlated with output and labor productivity.

In sum, labor productivity and its three components—factor inputs per hour, factor use, and TFP—along with various measures of innovation, are associated with the business cycle. If an economic downturn stifles innovation and capital formation, it could have persistent supply-side effects. Consequently, monetary policy could affect the economy's productive capacity by stimulating economic activity.

II. The Response of Labor Productivity to a Monetary Policy Shock

This section presents empirical evidence of the responses of labor productivity and its components to a surprise change in the stance of monetary policy. An expansionary monetary policy shock has a positive effect on labor productivity, reflecting a rise in factor use partly offset by a decline in factor inputs per hour. However, TFP has no significant response to the shock.

The dynamic responses of labor productivity and other macroeconomic variables to a monetary policy shock can be estimated with a structural vector autoregression (VAR) model. Such a statistical model relates each variable to past values of all variables in the model and to an error term that captures unexplained variations. A history of monetary policy shocks is recovered from the error terms under the identifying

assumption that no economic variable except the federal funds rate responds contemporaneously to such a shock, following Christiano, Eichenbaum, and Evans (1999).

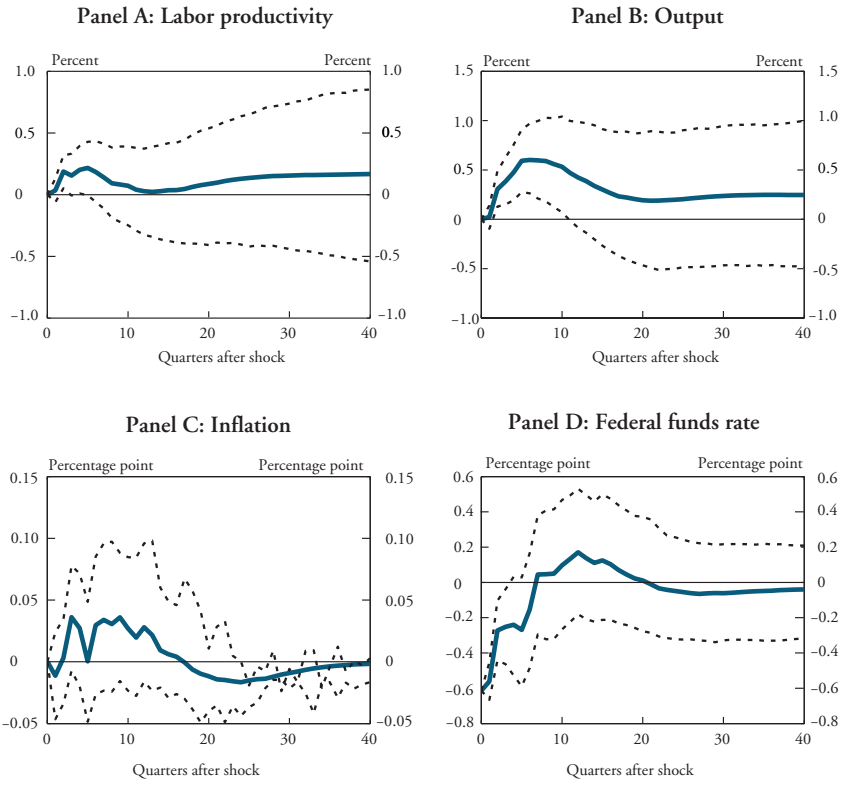
The equation for the federal funds rate in the VAR model thus consists of two parts. The first is an estimated monetary policy rule describing how policy responds systematically to key macroeconomic variables. While this first part may capture important interactions between labor productivity and the interest rate, it does not isolate labor productivity's response to an interest rate shock. The second part of the equation is the policy shock, which captures changes in the policy stance unrelated to any changes in the macroeconomic environment. Therefore, the analysis focuses on the response of labor productivity to a monetary policy shock, even though the systematic portion of monetary policy contributes to shaping the response. In particular, the systematic policy reaction to weak demand conditions could engender favorable supply-side effects not captured by analyzing the responses to a policy shock.[9]

Both a small and large model are estimated. The small model includes real output per hour in the business sector, real output in the business sector, the personal consumption expenditure price index, and the federal funds rate. The large model replaces output per hour with its components: TFP, factor inputs per hour, and factor use.[10] The lag length of the VAR is set to six quarters in the small model and two quarters in the large model, as determined by the Akaike information criterion. The sample covers the period from 1960:Q1 to 2007:Q4, which was the peak of the business cycle expansion prior to when the Federal Reserve embarked on its unconventional monetary policies.

An expansionary monetary policy shock temporarily raises labor productivity along with output and inflation. Chart 7 displays the impulse responses to a one-standard-deviation decline in the federal funds rate.[11] Because the article's main question is whether a temporary monetary policy shock has long-lasting effects, the chart shows the responses up to 10 years (40 quarters) after the shock. As Panel A shows, labor productivity rises for about one year after the shock before returning to its prior level. While the confidence band initially rises above zero, the subsequent response is not significantly different from zero. Panel B shows a larger response from output, implying hours worked also

Chart 7

Impulse Responses to a Monetary Policy Shock: Labor Productivity



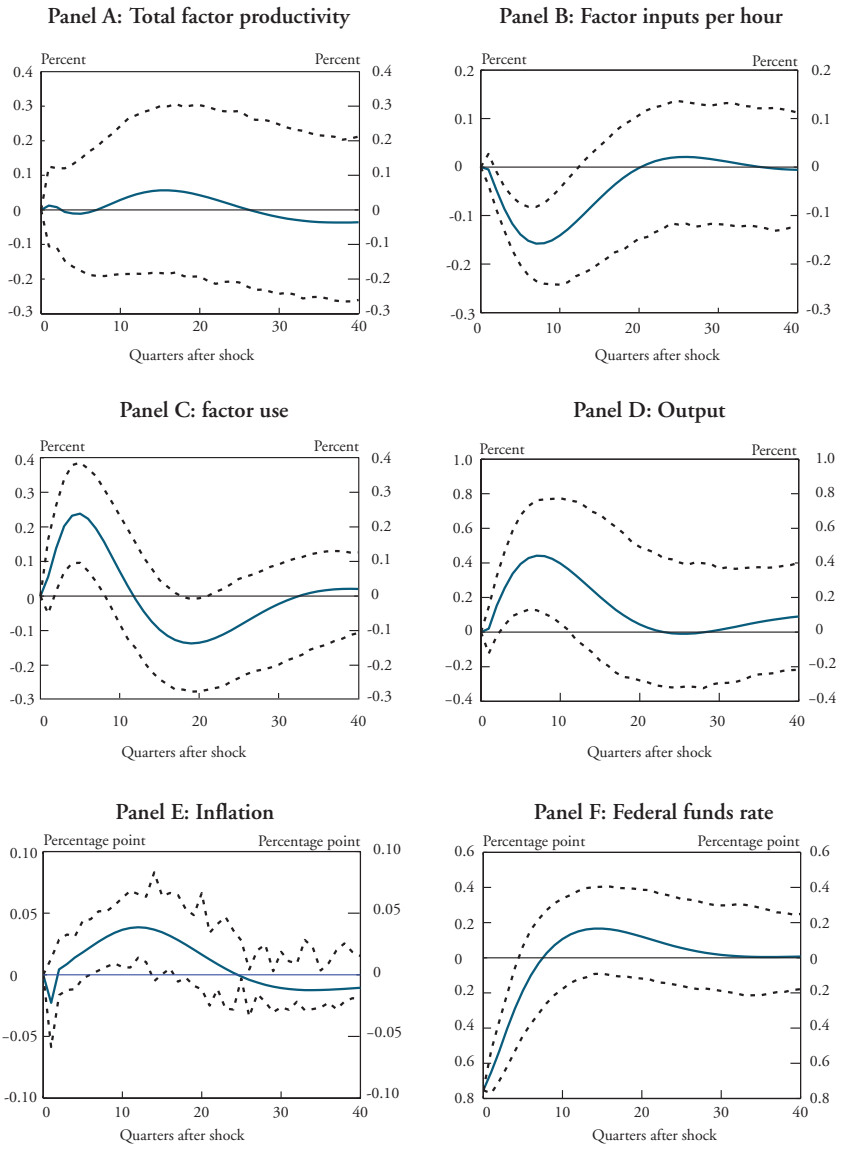
Note: Dashed lines indicate 95 percent confidence intervals.
Sources: Bureau of Economic Analysis, Bureau of Labor Statistics, Haver Analytics, and author's calculations.

rise. Panel C shows the response of inflation, which rises for about three years, though the rise is not statistically significant. Panel D shows the path of the federal funds rate, which drops contemporaneously with the shock before rising gradually for about two years.[12]

Labor productivity's dynamic response is the result of the differing responses of factor inputs per hour, factor use, and TFP. Chart 8 shows how these variables respond to an expansionary monetary policy shock. Panel A—the response of TFP to the shock—is of particular interest, as it may reflect improvements in technology. However, TFP is essentially unresponsive to the monetary policy shock, suggesting policy actions have no effect on the economy's productive capacity.

Chart 8

Impulse Responses to a Monetary Policy Shock: Components of Labor Productivity



Note: Dashed lines indicate 95 percent confidence intervals.
Sources: Fernald (2014), Bureau of Economic Analysis, Bureau of Labor Statistics, Haver Analytics, and author's calculations.

In contrast, the responses of factor inputs per hour and factor use are statistically significant but do not constitute evidence of supply-side effects. Panel B shows that factor inputs per hour decline: the increase in hours worked is large enough to offset any increases in labor quality and capital. The response returns to zero after about 20 quarters, suggesting no significant supply-side effects on labor productivity through capital deepening or higher labor quality.

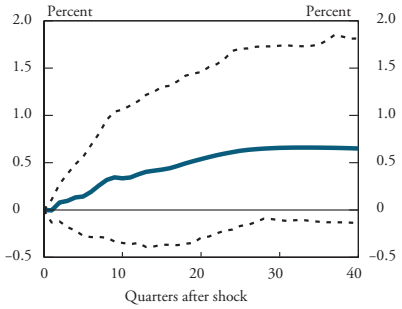
Panel C shows that factor use rises in response to the policy shock as the available capital and labor are employed more intensively. The positive, hump-shaped response of factor use mimics that of labor productivity, suggesting higher factor use is the dominant channel through which a monetary policy shock affects labor productivity. The response of labor productivity to a monetary policy shock thus reflects varying labor effort (labor hoarding) and a varying workweek of capital in response to temporary changes in demand, with no apparent supply-side effects. The dynamic responses of output, inflation, and the federal funds rate, shown in Panels C, D, and E, respectively, are similar to those reported in Chart 6, though the response of inflation is now statistically significant.

Evidence from more direct indicators of innovation suggests a monetary policy shock yields persistent supply-side effects. Chart 9 shows responses to an expansionary monetary policy shock in alternative versions of the small VAR model that replace labor productivity with one of three direct indicators of innovation. The first version uses the log of real R&D investment with the sample period 1960:Q1 to 2007:Q4. Panel A of Chart 8 shows R&D investment persistently rises by about one-half percent in response to the policy shock, but the response is not significantly different from zero. The second version replaces labor productivity with the rate of establishment births minus deaths, which shortens the sample period to 1993:Q2 to 2007:Q4. Panel B shows this measure of firm entry and exit responds positively, indicating that a surprise increase in monetary policy accommodation raises the rate at which new establishments open and/or lowers the rate at which old ones close. The third version uses net business formation, the measure of firm entry and exit available from 1954:Q3 to 1994:Q4, which also yields a significant, positive response to the monetary policy shock (Panel C).[13] Even a temporary increase in firm entry and exit can, in principle, have a long-lasting effect on trend labor productivity. However, whether the effect is

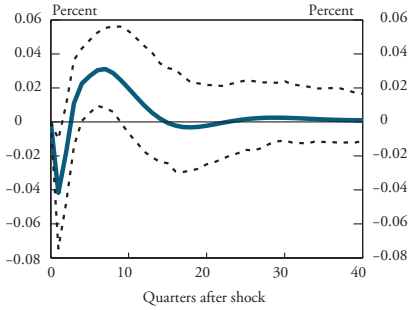
Chart 9

Impulse Responses to a Monetary Policy Shock: Innovation Indicators

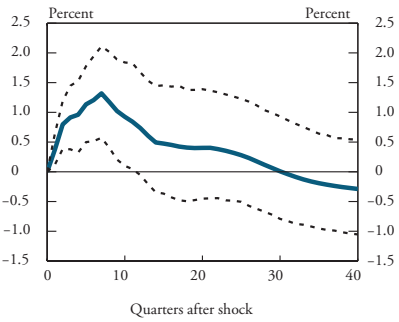
Panel A: Research and development investment



Panel B: Establishment births minus deaths



Panel C: Net business formation



Note: Dashed lines indicate 95 percent confidence intervals.
Sources: Bureau of Economic Analysis, Bureau of Labor Statistics, Haver Analytics, and author's calculations.

positive or negative depends on whether a higher entry rate or a lower exit rate dominates. More importantly, any such effects appear too weak to be manifest in the labor productivity data.

In summary, the evidence suggests that historically, expansionary monetary policy shocks have raised labor productivity through their effect on factor use with no gains in trend labor productivity, although the response of firm entry and exit implies limited supply-side effects. However, the sample period of the analysis ended in 2007, before the Federal Reserve had lowered the federal funds rate to its effective lower bound. The next section examines the effect of monetary policy on labor productivity in the period since the last recession.

III. The Current Recovery

Monetary policy has been highly accommodative in the current recovery. After the federal funds rate reached its effective lower bound, the Federal Reserve turned to unconventional monetary policy actions to provide additional accommodation. To measure the stance of policy in the current recovery, the analysis in this section replaces the effective federal funds rate with a shadow funds rate capturing the influence of unconventional policy at the zero lower bound. The results suggest unconventional monetary policies kept the level of accommodation over the course of the recovery roughly consistent with the systematic behavior of policy before the zero lower bound became a binding constraint. As a result, consistent with evidence from the pre-2008 period, monetary policy shocks had only a modest influence on labor productivity during the recovery. However, had the Federal Reserve not employed unconventional policies, the stance of monetary policy would have been tighter than its historical behavior would prescribe, leading to substantially lower labor productivity and output.

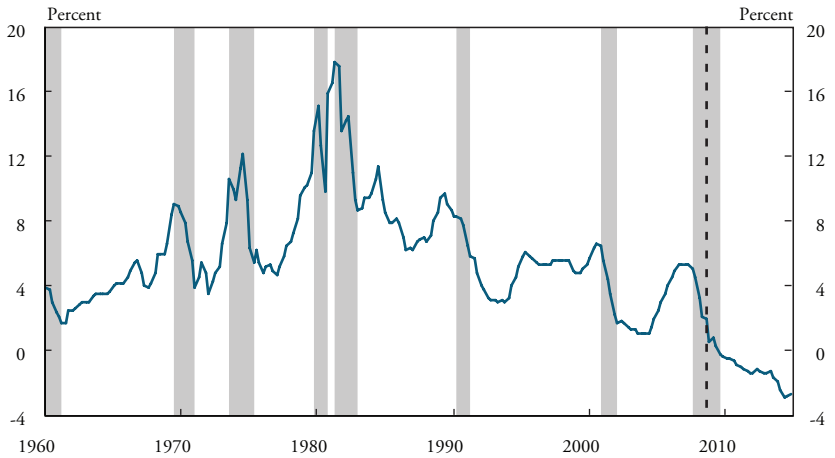
Measuring the stance of monetary policy in the current recovery

The VAR models in the previous section provide a framework to address whether monetary policy has been unusually accommodative during the current recovery and to what extent policy accommodation has prevented labor productivity from slowing further. However, measuring the stance of monetary policy over the last seven years, when the federal funds rate reached its effective lower bound and the Federal Reserve turned to large-scale asset purchases and forward guidance to provide additional accommodation, is difficult.

Although the federal funds rate ceased to be a good measure of the policy stance when it reached its lower bound, a shadow federal funds rate provides a measure based on longer-term bond prices. This article relies on the shadow federal funds rate of Wu and Xia to estimate the effects of monetary policy in the current recovery.[14] The shadow federal funds rate is equal to the effective federal funds rate until 2008:Q4 and deviates from then onward. Chart 10 shows that, after falling below zero in 2009:Q3, the shadow federal funds rate has continued to trend down, reaching -2.7 percent in 2014:Q4. To the extent the shadow rate captures the effects of unconventional monetary policy during the

Chart 10

Shadow Federal Funds Rate



Notes: Gray bars denote NBER-defined recessions. Data to the left of the vertical dashed line represent the effective federal funds rate. Data to the right of the dashed line represent Wu and Xia's shadow federal funds rate.
Sources: Federal Reserve, Haver Analytics, and Wu and Xia.

economic recovery, the VAR models can estimate how monetary policy shocks contributed to labor productivity after the recession.

If the shadow federal funds rate captures the stance of monetary policy in the current recovery in the same way the federal funds rate did prior to the recession, the dynamic relationships of the shadow federal funds rate with macroeconomic variables should remain unchanged. A formal statistical test cannot reject the hypothesis that macroeconomic variables have the same relationship with the lagged shadow federal funds rate since the start of the current recovery as they had with the effective federal funds rate before the recession.[15] Thus, evidence suggests the transmission of monetary policy to the economy has not changed significantly in the current economic recovery, when the shadow federal funds rate deviated from the effective federal funds rate. The impulse responses of labor productivity and output in the small VAR model (not shown) estimated in the extended sample from 1960:Q1 to 2014:Q4 are consistently similar to those based on the shorter sample from 1960:Q1 to 2007:Q4, suggesting the shadow rate is a useful measure of the post-recession stance of monetary policy.[16]

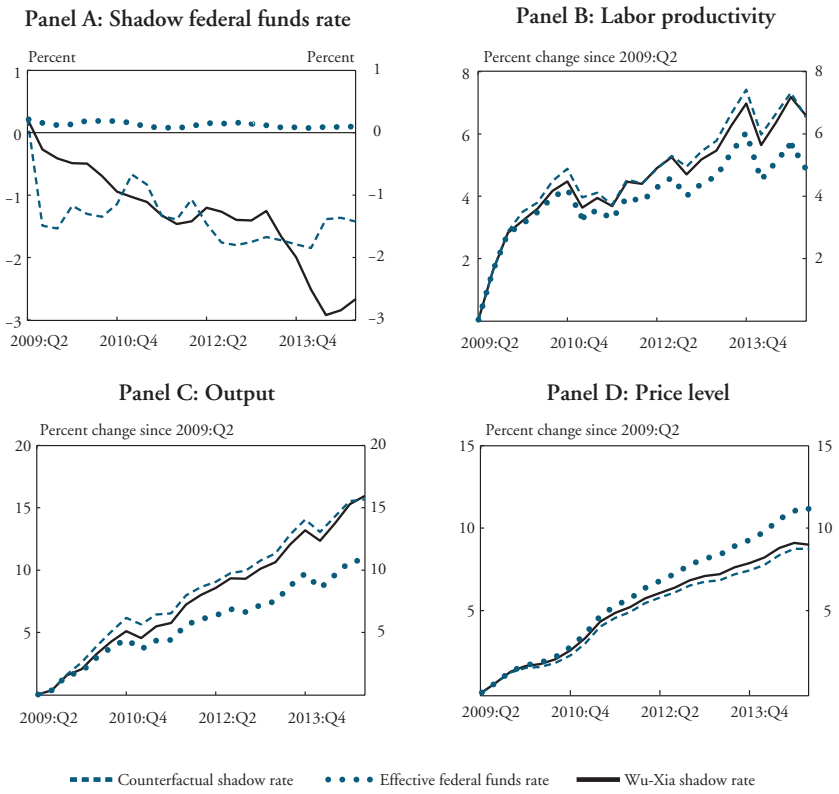
A historical decomposition shows that unconventional policies provided a degree of accommodation similar to what the Federal Reserve's systematic behavior would have prescribed for the federal funds rate had it not been constrained by the zero lower bound. Specifically, the decomposition yields the counterfactual path of the systematic portion of monetary policy by subtracting from the shadow federal funds rate the contribution of the estimated monetary policy shocks since 2009:Q3.[17] In Panel A of Chart 11, the dashed line labeled "counterfactual shadow rate" displays this counterfactual path alongside the Wu-Xia shadow rate (solid line). The panel shows that the counterfactual shadow rate—the rate prescribed by monetary policy's systematic behavior—fluctuated around a mean of -1.1 percent. Although the actual shadow rate remained well above the counterfactual in the first six quarters of the recovery, it declined well below the counterfactual in the most recent six quarters of the recovery. Because the expansionary shocks later in the recovery partly offset the preceding contractionary shocks, the Federal Reserve's unconventional policies appear, on average in the recovery, to have provided a level of accommodation roughly consistent with monetary policy's historical behavior.

Effects of monetary policy shocks

Monetary policy shocks had only a modest influence on labor productivity in the current recovery, as the negative effects of contractionary shocks were partly offset by the positive effects of expansionary shocks. The dashed line in Panel B of Chart 11 displays the counterfactual path for labor productivity alongside the actual data. Absent monetary policy shocks, labor productivity would have increased 6.7 percent from 2009:Q2 to 2014:Q4, just 0.1 percent less than the actual increase of 6.8 percent. Thus, labor productivity did not receive much of a boost from monetary policy shocks. Likewise, policy shocks had only a modest influence on output and the price level. Without policy shocks, output would have increased 17 percent from 2009:Q2 to 2014:Q4, just 0.3 percent less than the actual increase of 17.3 percent (Panel C). The personal consumption price index would have risen 9.1 percent, a bit below the actual increase of 9.4 percent (Panel D). The modest influence of policy shocks in the recovery reflects a level of accommodation in line with monetary policy's historical systematic behavior.

Chart 11

Actual and Counterfactual Macroeconomic Variables in the Economic Recovery



Notes: Solid lines show the actual paths of macroeconomic variables. Dashed lines show counterfactual paths had the shadow federal funds rate tracked its systematic behavior. Dotted lines show counterfactual paths had no unconventional monetary policies been pursued and had the only instrument of monetary policy been the effective federal funds rate.

Sources: Bureau of Economic Analysis, Bureau of Labor Statistics, Haver Analytics, Wu and Xia, and author's calculations.

Effects of unconventional monetary policy

A related question is what would have happened to labor productivity had the Federal Reserve not adopted its unconventional policy measures. Without these measures, the stance of monetary policy would have been substantially more restrictive than its systematic historical behavior prescribed. Therefore, an alternative exercise assumes the only instrument of monetary policy was the effective federal funds rate, which was constrained by the zero lower bound. The dotted line in Panel A of Chart 11 shows this rate (labeled "effective federal funds

rate"). The dotted lines in the remaining panels show the estimated paths of labor productivity, output, and the price level that would have prevailed in the absence of unconventional policies. Under this more restrictive policy path, labor productivity would have risen 5 percent by 2014:Q4, 1.8 percent less than the actual increase. Output would have risen 11.4 percent, 5.9 percent less than the actual increase. The price level would have increased by more than what has been observed.[18]

This exercise suggests the Federal Reserve's unconventional policy actions have substantially supported labor productivity in the current recovery. The difference between the actual and counterfactual paths of labor productivity, which accumulates to 1.8 percentage points or more than one quarter of the actual increase by 2014:Q4, may seem large. But the VAR model in this exercise ignores the nonlinearity introduced by the effective lower bound on the federal funds rate. The bound is imposed in the model through a sequence of contractionary policy shocks which surprise economic agents each quarter with a tighter-than-expected policy stance. However, in the real world, agents would have likely expected a prolonged period of near-zero interest rates even in the absence of the Federal Reserve's forward guidance, keeping financial conditions more accommodative than in the model's counterfactual. The results of the exercise can thus be viewed as an upper bound on the effects of unconventional policies. Nonetheless, even if the Federal Reserve's unconventional policy actions had half as large an effect as the exercise suggests, they would have substantially supported labor productivity in the current recovery.

IV. Conclusion

Various supply-side indicators are associated with the business cycle, suggesting monetary policy could influence the economy's supply side by stimulating economic expansion. These indicators include labor productivity, total factor productivity, R&D investment, and measures of firm entry and exit.

The analysis in this article indicates that historically, accommodative monetary policy shocks temporarily boost labor productivity by raising work effort and the workweek of capital. However, such shocks do not raise total factor productivity or lead to capital deepening, the

components of labor productivity more closely associated with the economy's productive capacity.

More recently, when the effective federal funds rate has been constrained by the zero lower bound, the Federal Reserve has used unconventional monetary policy tools to keep the level of monetary policy accommodation aligned with the accommodation it would have provided absent the zero lower bound. This accommodation appears to have boosted output and labor productivity substantially. Thus, the systematic response of monetary policy to weak economic conditions during the recession and recovery may well have prevented more severe supply-side damage and could reverse some of it over time.

Endnotes

[1]Van Zandweghe (2010) discusses more cyclical properties of labor productivity.

[2]A recession could also lower potential output by lowering the trend labor supply. When workers remain unemployed for a long period of time, their skills erode, their attachment to the labor force wanes, and their professional networks and connections dry up. As a result, they may have an increasingly difficult time re-entering the workforce, causing slack labor market conditions to turn into long-term unemployment or labor force nonparticipation. Erceg and Levin argue the bulk of the recent decline in labor force participation is due to the economic downturn, but Aaronson and others argue the decline is primarily due to trend factors such as the aging population. Other estimates lie in between; for instance, Van Zandweghe (2012) attributes about half of the decline in labor force participation to the economic downturn and half to trend factors.

[3]Fernald (forthcoming) identifies trend breaks in the growth of labor productivity and argues that the period from 1995:Q4 to 2003:Q4 was characterized by unusually rapid gains.

[4]The data were downloaded from *http://www.frbsf.org/economic-research/economists/jfernald/quarterly_tfp.xls.*

[5]Labor quality is measured by weighing workers with different observable skills by their relative wages, which proxy for their marginal productivity; see Fernald (2014).

[6]The unobserved fluctuations in labor effort and the workweek of capital are calculated based on observed fluctuations in hours per worker; see Fernald (2014) for details.

[7]Net business formation is from the Bureau of Economic Analysis (1996), and establishment births and deaths are from the Bureau of Labor Statistics. Both are quarterly series. The Business Dynamics Statistics from the Census Bureau are a good source for annual data on establishment entries and exits.

[8]Foster, Grim, and Haltiwanger find job creation fell by as much or more than job destruction in the recent recession. Consistent with their findings, the establishment entry rate in the Business Dynamics Statistics fell 2.9 percentage points from 2007 to 2009, and the exit rate increased just 0.7 percentage point in this period. This suggests that in the last recession, the sullying effect from fewer entries dominated the cleansing effect from more exits. Lee and Mukoyama find that the entry rate of manufacturing plants is more cyclical than the exit rate even before the last recession, though they emphasize that entering plants are less productive in expansions than in recessions.

[9]A related question is how the systematic behavior of monetary policy should change once policymakers recognize that changes in output may affect potential output. Reifschneider, Wascher, and Wilcox; and Ikeda and Kurozumi build channels from the demand side to the supply side into models of monetary policy analysis and study the implications for the conduct of monetary policy.

[10]Both models also include a commodity price index, which is added to limit the extent of a price puzzle. The index is the KR-CRB Spot Commodity Price Index for all commodities obtained from Haver Analytics. All variables in both VAR models are in log levels except factor use and the federal funds rate, which are in levels. This specification follows Boivin, Kiley, and Mishkin. The conclusions do not change when a linear trend is removed from the log of labor productivity and the log of output while the PCE price index enters in growth rates, as in Boivin and Giannoni.

[11]The dashed lines in the chart indicate 95 percent confidence intervals, which are obtained using the bootstrap procedure of Kilian.

[12]The impulse responses correspond qualitatively to those reported by Christiano, Eichenbaum, and Evans (2005), who estimate a larger VAR model including labor productivity from 1965 to 1995.

[13]The magnitude of the response of establishment births minus deaths is much smaller than that of net business formation, because the standard deviation of the monetary policy shock is smaller in the post-1993 period compared with the preceding period, and because the establishment measure is less responsive to a shock of the same size. The result for net business formation is consistent with results reported by Lewis, who shows that net business formation responds positively to an expansionary monetary policy shock using a VAR model with sign restrictions.

[14]While the measure of Wu and Xia is not the only shadow federal funds rate, it is updated monthly. The measure was downloaded from *http://faculty.chicagobooth.edu/jing.wu/research/data/WX.html.*

[15]The null hypothesis is that there is no break in 2009:Q3 in the estimated coefficients on the lagged shadow rate in the equations of the other macroeconomic variables. The likelihood ratio test statistic has an asymptotic chi-square distribution with degrees of freedom equal to the number of restrictions imposed under the null hypothesis (Wu and Xia; Hamilton). For the small VAR model, the test statistic is 22.53, and the p-value is 0.55; for the large VAR model, the test statistic is 18.77, and the p-value is 0.76.

[16]In contrast, inflation declines after an expansionary shock in the extended sample and increases in the shorter sample. The emergence of a price puzzle in the extended sample can be traced to the inclusion of the recession quarters from 2008:Q1 to 2009:Q2. While the transmission of monetary policy did not change significantly between the periods before and after the recession years, the recession itself may have been an exceptional period. For example, Ng and Wright argue that the last recession was unlike most other postwar recessions.

[17]The contribution of monetary policy shocks to a model variable y in any quarter t from 2009:Q3 (labeled t=1) and 2014:Q4 (t=22) is $\sum_{k=1}^{t} \Psi^{y}_{t-k} u_k$,where u_k is the monetary policy shock in quarter k and Ψ^{y}_{t-k} is the impulse response of y to a

unit monetary policy shock k quarters earlier. Subtracting this contribution from y generates a time series describing the counterfactual path of y in the absence of monetary policy shocks (see Wu and Xia).

[18]The higher price level in the counterfactual exercise with limited monetary policy accommodation reflects the price puzzle that emerged in the model estimated in the extended sample.

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