Productivity, monetary policy and financial indicators

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Introduction

Labour productivity is widely thought to be informative with regard to inflation and it therefore comes up frequently in discussions about the conduct of monetary policy. However, productivity growth is very difficult to interpret in real time. From a time series perspective, it is an unwieldy mixture of low-frequency trends and cyclical movements, with a generous dose of short-term noise thrown in. The net result is a very volatile series whose implications are difficult to grasp even in hindsight. However, if productivity does offer the prospect of information about inflation, it is worth making an effort to go beyond the surface noise. In that spirit, this paper considers why it may be helpful to pay attention to productivity in monetary policy and examines the possible use of financial indicators to obtain information about cyclical fluctuations in productivity growth in real time.

The main reason that productivity is thought to be helpful in monetary policy is that it may contain information about future inflation. This information may be directly about inflationary trends, or it may be about real trends (say in potential output) which could indirectly shed light on future inflation. A brief review of the relevant research suggests that there are definitely some theoretical relationships that should be explored, but that the empirical obstacles are far from easy to clear. Nevertheless, there is some empirical evidence that monetary policy in the United States has reacted to changes in productivity growth since the 1950s.

If knowing about productivity growth is helpful over the business cycle, but it is hard to measure, can we find any simple indicators that are related to productivity growth with any degree of robustness? We consider here a handful of financial indicators, all easy to track, and all exhibiting some degree of correlation with productivity growth over the business cycle. In order to bring to the fore the cyclical relationships, it is necessary to filter the data to exclude long-term trends and short-term noise. For these purposes, we apply standard techniques that allow us to split the movements of each variable into components that move in a single frequency or in a range of similar frequencies.[2] The results vary substantially across financial indicators, but they suggest that the federal funds rate, the spread between rates on short- and long-dated US Treasury securities, and the returns on the S&P 500 all contain meaningful information about cyclical movements in US labour productivity in real time.

1. Productivity and monetary policy

Why is it important for monetary policymakers to consider the growth in labour productivity in their deliberations? If the main goal of monetary policy is to keep inflation in an acceptable range, we must conclude that knowing about labour productivity is helpful if it ultimately sheds some light on the issue of inflation. We examine three possibilities. First, that productivity may contain direct information about future inflation. Second, that productivity may contain information about other variables, say potential output or the output gap, which in turn may contain information about future inflation. Third, that productivity and inflation may be simply statistically related over the business cycle, and knowing about one or acting on it may have consequences for the other.

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[1] The views expressed in this paper are those of the author and do not necessarily represent those of the Federal Reserve Bank of New York or the Federal Reserve System.

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[2] A technical discussion of the techniques applied here can be found in Estrella (2003).

Consider first the possibility of a direct connection between productivity and inflation. In the United States, the 1970s brought the confluence of two unwelcome events, a noticeable drop in labour productivity growth and an even more noticeable rise in the rate of inflation. From the early 1980s, there was a surge in journal articles examining possible direct connections between productivity and inflation.[3] This literature identified a strong negative empirical correlation between the two variables and offered a series of theoretical arguments to help explain the facts.

Some of the arguments suggested that causality went from productivity to inflation. For instance, a slowdown in productivity growth could reduce aggregate supply and, other things equal, lead to a rise in the aggregate price level. Other arguments had causality going in the opposite direction. For example, a rise in inflation could distort incentives and lead to adverse changes in employment, savings, investment and trade. Alternatively, higher inflation could increase aggregate uncertainty, which could then disrupt business plans. Some of the empirical evidence, particularly the evidence based on vector autoregressions, suggested that it was most likely that causality went from inflation to productivity.[4]

Either way, there would be implications for monetary policy. If productivity growth tended to reduce inflation, monetary policymakers would have to factor current productivity growth into their decision-making so as to avoid over- or underreacting. If inflation lowered productivity growth, policymakers would have an added impetus to control inflation, although the information content of productivity would be less of a factor.

The second possibility is that productivity influences variables, such as potential output, which may have either a causal effect on, or a predictive connection with, future inflation. A standard view in current macroeconomics is that the output gap, the difference between actual and potential output, helps predict inflation. This view is embodied in the Phillips curve, based on an original proposal by Phillips (1958).[5] If higher productivity growth is consistent with faster sustainable output growth, a given level of actual output produces a smaller output gap and lower future inflation.

The third possibility is that productivity growth and inflation are not causally related in any clear way, but are merely statistically correlated. If the correlation were such that productivity were a leading indicator of (lower) inflation, and if it were persistent and robust, information about productivity could be used almost as in the causal circumstances, perhaps with a bit more caution and scepticism. However, if productivity is inversely related to contemporaneous inflation, as some of the evidence suggests, policymakers may find that they get extra benefit from keeping inflation under control (and thus have an extra incentive to do so).

To put the discussion in perspective, we end this section with a small macroeconomic model of the United States that clarifies some of the empirical questions and asks whether policymakers have taken productivity into account in their decisions since the 1950s. The model is a vector autoregression (VAR) using quarterly data from the first quarter of 1955 to the first quarter of 2003. There are four variables in the model: non-farm productivity growth, CPI inflation, non-farm output growth and the federal funds rate. The first three variables, obtained from the US Department of Labor, are measured as first differences of logs. The interest rate is in per cent per annum and is obtained from the Federal Reserve. Three lags of each variable are included in each equation.[6]

We present two types of results to examine the implications of the model. First, the results of Granger causality tests for the VAR are shown in Table 1. They indicate the level of importance of lags of each variable in each of the four individual equations, and provide some direct information about the estimates. Second, Figure 1 shows impulse responses to shocks in each of the four variables of the model, which help isolate the effects of the individual variables.

The first line of Table 1 indicates that no variable is very significant in explaining productivity growth. One interpretation could be that productivity growth is to some extent exogenous, that is, it does not

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3 For example Clark (1982), Jarrett and Selody (1982), Ram (1984) and Cameron et al (1996).

4 For example Ram (1984). However, Sbordone and Kuttner (1994) and Saunders (1998) find that the negative relationship disappears if the model controls for monetary policy.

5 See eg Gali and Gertler (1999) for a recent application.

6 A preliminary test using the Akaike information criterion suggests this is an appropriate lag length.

react to changes in other variables. Another possibility is that the variable, as mentioned earlier, is dominated by short-term noise, which is impossible to predict. Perhaps if it were possible to eliminate that noise, the relationships would be clearer. We come back to this point in the next section.

The second line in the table shows that output reacts to changes in both productivity and the federal funds rate. The relationship with the funds rate is consistent with earlier research that shows that this rate is a good indicator of the stance of monetary policy, which is expected to affect output within a few quarters, as in the model.[7] Inflation is very persistent, and its own lags are very significant, as indicated in the table.[8] Otherwise, it seems to be affected only by lags in the funds rate. We need to exercise caution with regard to this last relationship, however, since the sign of the relationship is not necessarily what we would expect.[9]

The final line in the table may be interpreted as a crude model of the "Fed reaction function", the extent to which policy reacts to observable macroeconomic variables.[10] The results suggest that policy reacts strongly to the lagged funds rate, output and inflation, and less strongly to productivity growth.

The impulse responses in Figure 1 are based on the ordering shown in the table, and the shock to each variable is of a magnitude equal to the standard error of the corresponding equation. By construction, the results are consistent with the Granger causality results, but afford a somewhat different perspective. The last row, for instance, corresponds to the last row of Table 1, the "Fed reaction function". We see in the figure that the funds rate, output and inflation are all significant, as expected, and that they have the expected signs. In addition, the figure indicates that the policy reaction to productivity is also statistically significant for some horizons, albeit of a smaller magnitude than the reaction to other variables.

In the row corresponding to inflation, we see manifestations of several of the patterns that have been discussed before. First, the persistence of inflation is apparent in the slow decline of this variable in response to a shock in itself. Second, the Phillips curve relationship that predicts that higher growth will lead to higher inflation is clear in the third panel. Third, we see the price puzzle in the final panel of the row: inflation seems to rise in response to a positive shock in the funds rate. Though somewhat disturbing, this response is short-lived and relatively small.

For output, we see indications of an "IS equation" in the last panel of the row. An upward shock to the funds rate leads to a noticeable drop in output, particularly two quarters ahead. Finally, we see in the upper left-hand panels of the figure some evidence that productivity and inflation react negatively to one another, as some of the earlier literature has suggested. Some of these results are statistically significant, though they are all fairly small.

2. Productivity and financial indicators at business cycle frequencies

We turn now to the cyclical correlations between productivity growth and several financial indicators. As noted earlier, the purpose here is to determine whether easily accessible financial indicators can shed some light on the current situation in the productivity cycle. In addition to the federal funds rate, which we used in the previous section, we include the three-month Treasury bill rate, the 10-year Treasury bond rate, and the term spread between these two rates.[11] We also include the return on the S&P 500 Index (first difference of the log) and, to look at the direct correlation between productivity and inflation over the business cycle, the CPI inflation used in the previous section.

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7 Bernanke and Mihov (1998), for example, suggest that the funds rate is the best single indicator of the stance of monetary policy in the United States.

8 See Fuhrer and Moore (1995).

9 This "price puzzle" is found in virtually every VAR of this type. For a discussion, see Sims (1986).

10 See, for example, Clarida et al (2000).

11 Data for all the interest rates were obtained from the Federal Reserve.

We focus on business cycle frequencies by operating within the frequency domain.[12] This allows us to measure correlations, leads and lags that pertain only to the frequencies of interest. Specifically, we look at averages over frequencies corresponding to cycles of 11 to 28 quarters (roughly three to seven years) in length. Empirical evidence shows that these frequencies are representative of the US business cycle.

To illustrate the effects of focusing on business cycle frequencies only, Figure 2 compares the business cycle component of productivity with the untransformed productivity growth series. The filtered productivity series eliminates both the short-term noise that makes the growth series very hard to interpret and long-term trends that have slow-moving effects on the series. The business cycle pattern that emerges is clear, and we can observe its relationship with NBER-dated recessions, which are shaded in the figure.

Table 2 contains several measures of the relationship between productivity growth and each of the financial indicators (and inflation). Coherence is a correlation measure that indicates how strongly the two variables are related at business cycle frequencies. It ranges from 0 (no correlation) to 1 (perfect correlation). The caveat is that this correlation may not be contemporaneous, but may involve a lead or a lag. A measure of the magnitude of this lead or lag is the phase lead, presented next in the table. The (weighted) average of the business cycle frequencies is about 16 quarters. Thus, a phase lead of 0 quarters means that the relationship is contemporaneous, and a phase lead of eight quarters, or half a cycle, means that the contemporaneous relationship is essentially negative.

The final measure in Table 2 is the in-phase correlation, which is similar to the coherence, but focuses only on contemporaneous correlation. It also has a sign that indicates the direction of the relationship. If the coherence and in-phase correlation of a pair of variables are about the same size (in absolute value), the phase lead is small. Conversely, a high coherence with a low or negative in-phase correlation is indicative of a substantial phase lead or lag.

In Table 2, coherence with productivity is fairly high and statistically significant for all indicators. The usefulness of this result stems from the fact that it confirms that all these variables have substantial variation at business cycle frequencies. Unfortunately, it helps very little in differentiating among indicators of cyclical productivity growth in terms of quality or timing.

Turning to the next measure in the table, the phase leads are small for both the term spread and the stock index, neither of which is significantly different from zero. This is a sign that the relationships with productivity growth are roughly contemporaneous and that these variables show some promise as coincident indicators. The lags for interest rates are all relatively large, but this is not necessarily a problem. None of the lags are significantly different from eight quarters, which indicates that there may be a high, but negative, contemporaneous correlation with productivity growth.

These results are confirmed by looking at the in-phase correlations, which are high and close in absolute value to the coherence for most of the interest rate and stock variables. Only the correlation for the 10-year bond rate is less than one half in absolute value. Graphical evidence that provides visual confirmation of the results of Table 2 is presented in Figure 3, which shows the business cycle components of the variables in the time domain. It is clear from the various panels of Figure 3 that the federal funds rate and the term spread have particularly tight relationships with productivity at these frequencies over most of the sample period, which accords with the ranking of the in-phase correlations in Table 2.

Inflation is also included in Table 2, and the results indicate that inflation, much like the short-term interest rates, has a strong negative relationship with productivity over the business cycle. As argued in the previous section, one interpretation of this result, even if it is purely statistical, is that monetary policymakers have an additional incentive to keep inflation cyclically low, since low cyclical inflation is regularly accompanied by high cyclical productivity growth.

One drawback of using the financial indicators in the foregoing manner is that it requires computation of the cyclical components of the financial variables, as well as for productivity. How much information

[12] Time series are transformed into the frequency domain by taking Fourier transforms. For details, see Appendix 2 in Estrella (2003).

about cyclical productivity may be gleaned from the financial series directly, without resorting to frequency domain methods?

Table 3 suggests that some useful information can in fact be obtained simply by looking at the financial series. The first column of the table shows the in-phase correlation from Table 2. The second column, however, correlates the cyclical component of productivity with the untransformed financial indicators. We see that the correlations are lower (in absolute value), though most are not insubstantial. The largest correlation is for the term spread, which has a value of 41%. The federal funds rate and the stock index are both at 29%, which is still somewhat informative. The worst case is the bond rate, which is clearly not very reliable.[13]

To gauge the gains from the frequency domain analysis of productivity, the final column of Table 3 shows the correlation of the untransformed financial indicator with untransformed productivity growth. The difference between this measure and the others is most notable in the case of the term spread, whose correlation with directly observable productivity growth is only 18%. Once the short-term noise and the trends are removed from productivity growth, the correlation of its cyclical component with the term spread rises to 41%, and the in-phase correlation is 72%. We also see gains for the funds rate and the stock index, although of more modest magnitude.

3. Conclusions

The analysis of this paper suggests that information about the movements of labour productivity growth over the business cycle may be useful to monetary policymakers for various reasons, both direct and indirect. The empirical analysis shows that there are statistically significant relationships consistent with the theoretical usefulness of productivity and, moreover, that the data are consistent with US monetary policy taking productivity growth into account since 1955.

The paper also shows that financial indicators may be somewhat helpful in interpreting the noisy productivity growth series, in particular by serving as coincident indicators of the cyclical component of productivity growth. The strongest signals are derived from the term spread, the federal funds rate and growth in the S&P 500 Index.

Results for some of the financial indicators are statistically significant, though they may not seem particularly impressive. To put these in perspective, however, it is helpful to bear in mind that looking at the productivity growth series itself is not highly informative, as Figure 2 shows. In other words, one needs all the help one can get.

[13] A useful benchmark for these correlations is the correlation between the untransformed productivity growth series and its own business cycle component, which is 30%. Note that the business cycle component of productivity growth is more highly correlated with the observable term spread and about as correlated with the actual federal funds rate and stock index growth. I am grateful to Eduardo Loyo for suggesting this comparison.

Table 1: The table reports p-values for the exclusion tests of the lags of the variables named in each column from the forecasting equation of the variable named in each row.

Table 1

Granger causality tests for four-variable vector autoregression

1955 Q1 to 2003 Q1

Dependent variable	Productivity	Output	Inflation	Fed funds rate
Productivity	.20	.11	.06	.10
Output	.00	.00	.21	.00
Inflation	.70	.32	.00	.00
Fed funds rate	.06	.00	.02	.00

Note: Productivity, output and inflation are first differences of logs and the federal funds rate is in per cent per annum. Each equation includes a constant term and three lags of each variable.

Table 2

Coherence, phase lead of productivity, and in-phase correlation with productivity at business cycle frequencies

1955 Q1 to 2000 Q4

Variable	Coherence (t-statistic)	Phase lead (standard error)	In-phase correlation (t-statistic)
Fed funds rate	.812 (5.32)	–7.03 (1.24)	–.746 (–4.52)
3-month T-bill rate	.772 (4.81)	–7.03 (1.45)	–.691 (–3.99)
10-year T-bond rate	.571 (3.04)	–5.68 (2.53)	–.319 (–1.55)
Term spread	.721 (4.26)	.25 (1.69)	.717 (4.23)
S&P 500 Index	.645 (3.60)	1.03 (2.08)	.597 (3.23)
CPI inflation	.701 (4.08)	–7.26 (1.79)	–.652 (–3.65)

Note: The business cycle is defined by cycle lengths of 11 to 28 quarters, centred at a weighted average of 16 quarters. For coherence and in-phase correlation, significance is calculated with respect to an arctanh transformation and a t-statistic is given. For phase lead, a standard error is provided to gauge the significance of differences from values other than zero, eg from half the mean cycle length of 16 quarters.

Table 3

Correlations with productivity at business cycle frequencies and all frequencies

1955 Q1 to 2000 Q4

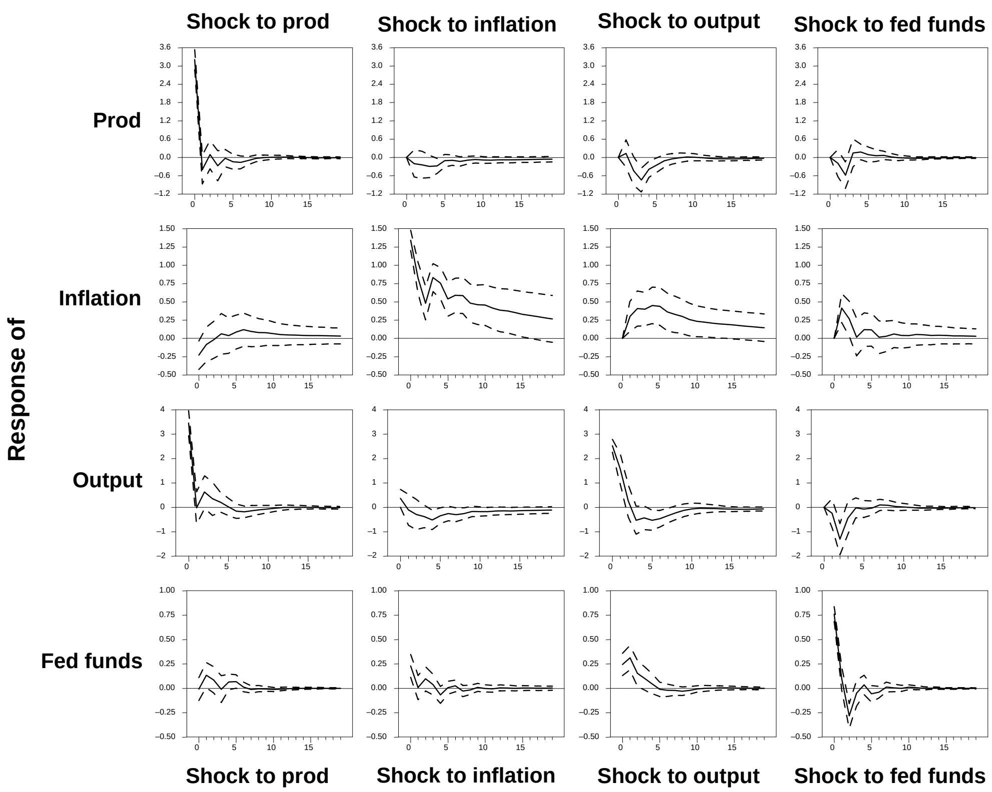
Variable	BCF productivity BCF variable	BCF productivity AF variable	AF productivity AF variable
Fed funds rate	–.746	–.285	–.259
3-month T-bill rate	–.691	–.234	–.230
10-year T-bond rate	–.319	–.073	–.166
Term spread	.717	.405	.184
S&P 500 Index	.597	.288	.215

Note: BCF means business cycle frequencies only; AF means all frequencies (untransformed variable). BCF for both productivity and variable produces the in-phase correlation of Table 2. The business cycle is defined by cycle lengths of 11 to 28 quarters, centred at a weighted average of 16 quarters.

Figure 1

Impulse responses for four-variable vector autoregression

1955 Q1 to 2000 Q4

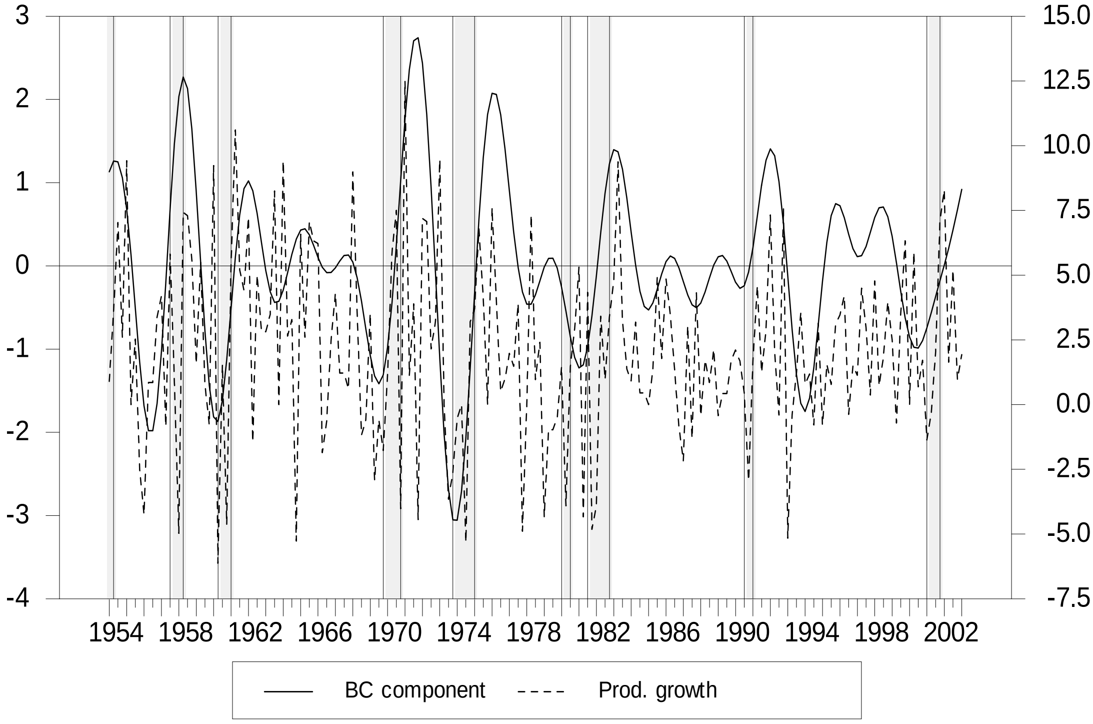


Note: The magnitude of each shock is the residual standard error for the corresponding equation. Contemporaneous ordering is as listed. Dashed lines represent a 95% confidence band using standard errors computed by Monte Carlo integration (see Sims and Zha (1999)).

Figure 2

Productivity growth and its business cycle component

1954 Q1 to 2002 Q4

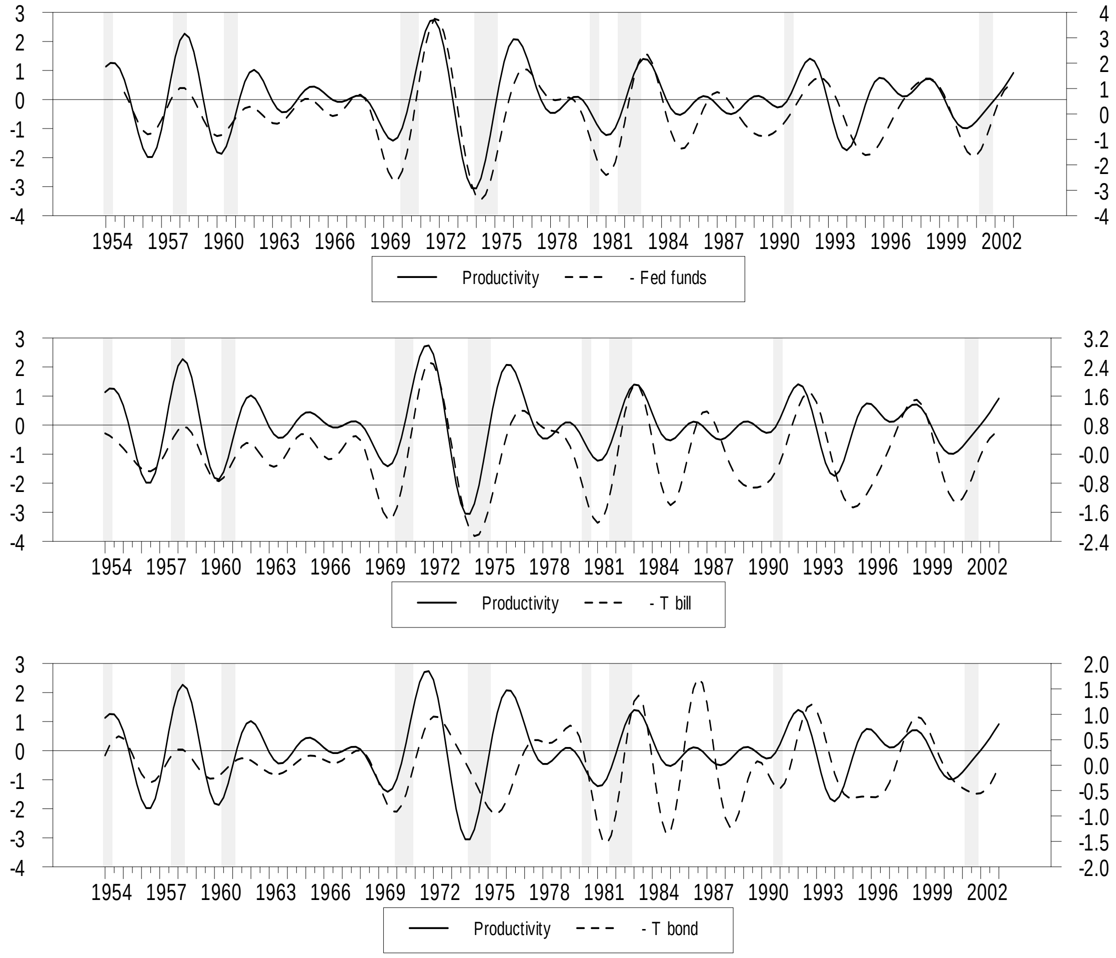


Note: The business cycle component is derived by focusing on business cycle frequencies in the frequency domain, retaining cycles of 11 to 28 quarters. Left scale is for solid line, right scale for dashed line. Federal funds series starts in 1955. Shading denotes NBER recession dates.

Figure 3a

Business cycle components of productivity growth and financial indicators

Interest rate indicators (with negative signs to make the correlations positive)
1954 Q1 to 2002 Q4

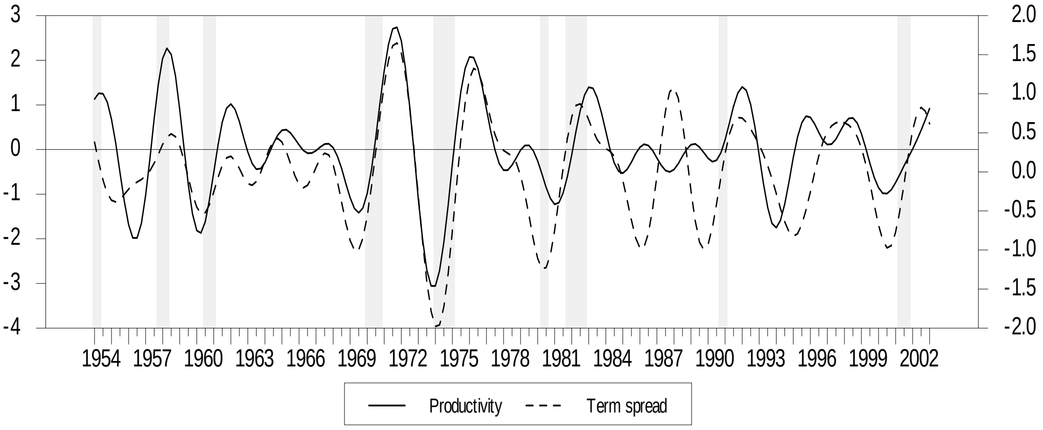


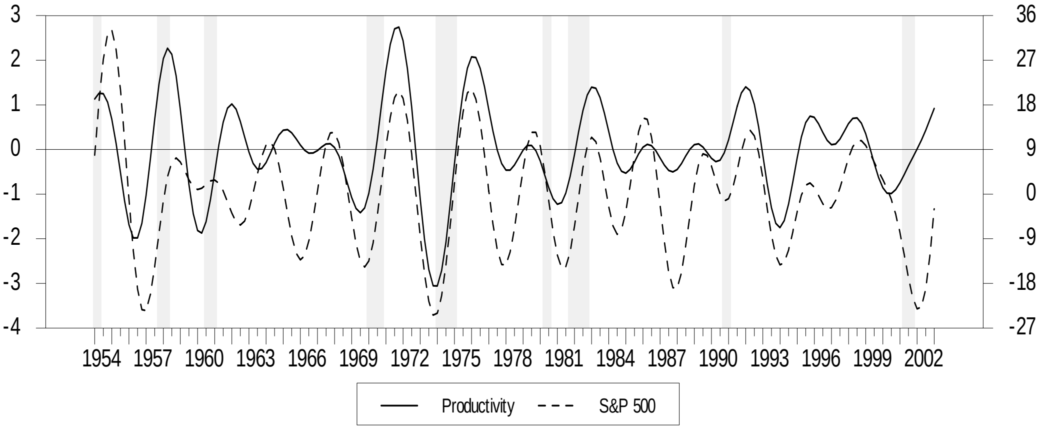
Note: Business cycle components are derived by focusing on business cycle frequencies in the frequency domain, retaining cycles of 11 to 28 quarters. Left scale is for solid line, right scale for dashed line. The federal funds series starts in 1955.

Figure 3b

Business cycle components of productivity growth and financial indicators

Term spread and S&P 500 Index
1954 Q1 to 2002 Q4





Note: Business cycle components are derived by focusing on business cycle frequencies in the frequency domain, retaining cycles of 11 to 28 quarters. Left scale is for solid line, right scale for dashed line.

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