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**THE LONG AND LARGE DECLINE IN  
U.S. OUTPUT VOLATILITY**

Olivier Blanchard, MIT  
John Simon, Reserve Bank of Australia

Working Paper 01-29  
April 2001

Room E52-251  
50 Memorial Drive  
Cambridge, MA 02142

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# The long and large decline in U.S. output volatility.

Olivier Blanchard and John Simon \*

April 20, 2000

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\*MIT and NBER, and Reserve Bank of Australia respectively. We thank the editors and our discussant, Benjamin Friedman, for comments. The paper builds on Simon's MIT Ph.D. thesis [2000]. We thank Robert Solow, and participants in the MIT macro lunch for comments. The views in this paper are those of the authors and should not be attributed to the NBER or Reserve Bank of Australia.

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**Abstract**

The last two U.S. expansions have been unusually long. One view is that this is the result of luck, of an absence of major adverse shocks over the last twenty years. We argue that more is at work, namely a large underlying decline in output volatility. This decline is not a recent development, but rather a steady one, starting in the 1950s, interrupted in the 1970s and early 1980s, with a return to trend in the late 1980s and the 1990s. The standard deviation of quarterly output growth has declined by a factor of 3 over the period. This is more than enough to account for the increased length of expansions.

We reach two other conclusions. First, the trend decrease can be traced to a number of proximate causes, from a decrease in the volatility in government spending early on, to a decrease in consumption and investment volatility throughout the period, to a change in the sign of the correlation between inventory investment and sales in the last decade. Second, there is a strong relation between movements in output volatility and inflation volatility. This association accounts for the interruption of the trend decline in output volatility in the 1970s and early 1980s.

Since the early 1980s, the U.S. economy has gone through two long expansions. The first, from 1982 to 1990, lasted 33 quarters. The second, which started in 1991, is giving signs of faltering. But it is in its 38th quarter, and is already the longest U.S. expansion on record.

One view is that these two long expansions are simply the result of luck, of an absence of major adverse shocks over the last twenty years. We argue in this paper that more has been at work, namely a large underlying decline in output volatility. Furthermore, we argue, this decline is not a recent development—the by-product of a “New Economy” or of Alan Greenspan’s talent—but rather a steady one, starting in the 1950s (or earlier, but this is difficult to establish, because of a lack of consistent data), interrupted in the 1970s and early 1980s, with a return to trend in the late 1980s and the 1990s.<sup>1</sup> The magnitude of the decline is substantial: The standard deviation of quarterly output growth has declined by a factor of 3 over the period. This is more than enough to account for the increased length of expansions.

Having established this fact, we reach two other conclusions. First, the decrease can be traced to a number of proximate causes, from a decrease in the volatility in government spending early on, to a decrease in consumption and investment volatility throughout the period, to a change in the sign of the correlation between inventory investment and sales in the last decade. Second, there is a strong relation between movements in output volatility and movements in inflation volatility. The interruption of the trend decline in output volatility is associated with a large increase in inflation volatility in the 1970s; the return to trend is associated with the decrease in inflation volatility since then.

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<sup>1</sup>What has happened to output volatility over a much longer time span has been the subject of a well known debate, to which we do not return. See Romer [1986], Weir [1986], and Balke and Gordon [1989].

Our paper is organized as follows. We start by presenting our basic fact, namely the decrease in output volatility. We then look at the stochastic process for GDP, and show that the decrease in volatility can be traced primarily to a decrease in the standard deviation of output shocks, rather than to a change in the dynamics of output. Finally, we show how this decrease in the standard deviation of innovations accounts for the increase in the length of expansions.

We then take up the question of whether recessions are special, in a way the formalization used earlier does not do justice to. Put another way, we take up the question of whether what we have seen over the last twenty years is simply the absence of large shocks and nothing more. We show that this is not the case. The measured decrease in output volatility has little to do with the absence of large shocks in the recent past.

We then turn to the relation between output volatility and inflation. We show that there is a strong relation both between output volatility and the level of inflation, and between output volatility and inflation volatility. Both volatilities went up in the 1970s, and have come down since. Correlation does not, however, imply causality. Both evolutions may for example be due to third factors, such as supply shocks in the 1970s. This leads us to consider the evidence from the G7 countries. Our motivation is that the different timings of disinflation across the countries can help separate out the effects of inflation from those of supply shocks. We first show that these other countries have also experienced a decline in output volatility, although with some differences in timing and in magnitude. An interesting exception is Japan, where a decline in output volatility has been reversed since the late 1980s. We then show that, even after controlling for common time fixed effects, inflation volatility still appears to be strongly related to output volatility.

As a matter of accounting, the decline in output volatility can be traced either to changes in its composition, or to changes in the variance and co-

variances of its underlying components. With this motivation, we look at the components of GDP. We find that, at least at the level of disaggregation at which we operate, changes in composition explain essentially none of the trend decline. Composition has changed, but the effects of the various changes have mostly cancelled each other. We also find that, apart from a decrease in the volatility of government spending early on in the period, most of the decrease in output volatility can be traced to a decrease in both consumption and investment volatility, and more recently to a change in inventory behavior, with inventory investment becoming more countercyclical.

We conclude by discussing the agenda for further research. In particular, it is clear that we have only gotten to the proximate causes of the volatility decline. The deeper causes, from changes in financial markets to better counter-cyclical policy, remain to be identified.

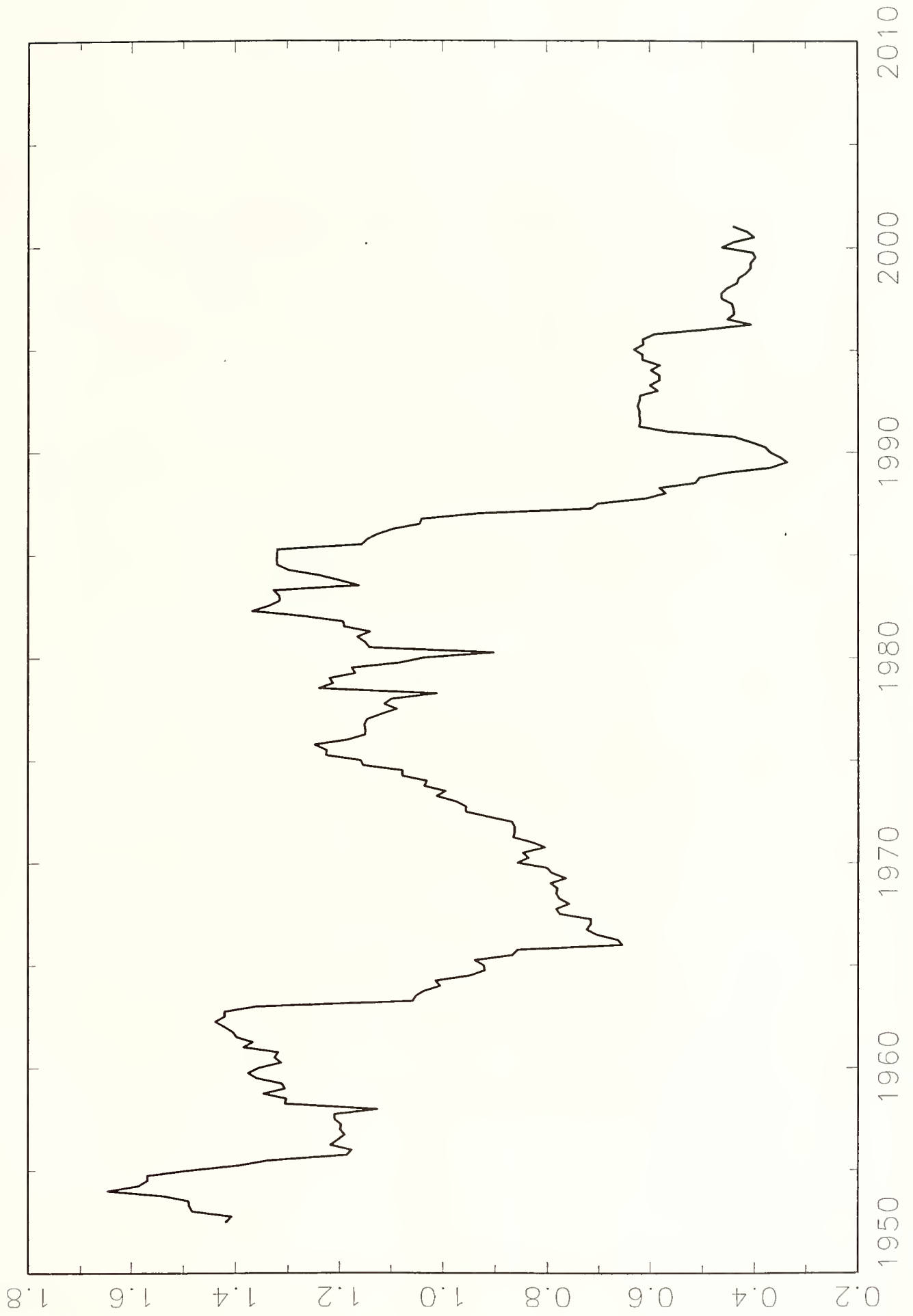
## 1 The decline in output volatility

Figure 1 shows the evolution of the rolling standard deviation of quarterly real output growth (measured at a quarterly rate), since 1952:1. The measure of output is chain-weighted GDP. We use a window of 20 quarters, so the standard deviation reported for quarter  $t$  is the estimated standard deviation over quarters  $t - 19$  to  $t$ . The first available observation for chain-weighted GDP is 1947:1, so the first observation for the standard deviation of the growth rate is 1952:1.

The figure shows a clear decline in the standard deviation over time, from about 1.5% per quarter in the early 1950s to less than 0.5% in the late 1990s. The decline is not continuous: Volatility increases from the late 1960s to the mid-1980s, followed by a sharp decline in the second half of the 1980s.

One may think of other ways of measuring volatility. An alternative is to

Figure 1. Output growth  
Rolling standard deviation



look at the standard deviation of the deviation of the *level* of (the logarithm of) output from trend, for example, from a Hodrick-Prescott filter.<sup>2</sup> Another is to look at annual rather than quarterly changes in GDP. These alternatives yield very similar conclusions. The basic reason is that the standard deviation of quarterly output growth reflects primarily the high frequency properties of the series, which are largely invariant to the detrending method.

### Changes in the output process

The natural next step is to think about the process generating output movements over time, and ask how it has changed. Does the lower volatility of output reflect a lower standard deviation of output shocks, or a change in the dynamic process through which these shocks affect output, or both?

More concretely, assume that output growth follows an autoregressive process given by:

$$(\Delta y_t - g) = a(L)(\Delta y_{t-1} - g) + \epsilon_{Yt} \quad (1.1)$$

where  $y_t$  denotes the logarithm of output in quarter  $t$ ,  $\Delta$  denotes a first difference,  $g$  is the underlying growth rate of output,  $\epsilon_{Yt}$  is a white noise shock with standard deviation  $\sigma_\epsilon$ , and  $a(L)$  is a lag polynomial.

The standard deviation of output  $\sigma_y$  then depends both on the standard deviation  $\sigma_\epsilon$  and on the lag polynomial  $a(L)$ . If  $a(L) = a$ , for example, output growth follows a first order autoregressive process and  $\sigma_y = \sigma_\epsilon / \sqrt{1 - a^2}$ , so the higher  $a$ , the higher is the standard deviation of output.

With these points in mind, we estimate (1.1) over a rolling sample from 1947:1 on, again with a window of 20 quarters. We assume the process to be AR(1); while this does not fully capture the dynamics of output growth, it makes for an easier interpretation of the changes in the process, and all

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<sup>2</sup>This is the approach taken by Taylor [2000].



of our conclusions extend to a higher order AR. The results are plotted in Figure 2. The top panel gives the estimated growth rate. The middle panel gives the estimated AR(1) coefficient. The bottom panel gives the estimated standard deviation of the shock. The other two lines in each panel give two-standard-deviation bands on each side of the estimate.

The conclusions from Figure 2 are straightforward. Neither the growth rate nor the AR(1) coefficient show clear movements over time. The AR(1) coefficient is slightly lower at the end of 1990s than in the rest of the sample, but the difference is not significant.<sup>3</sup> The standard deviation of the output shock shows the same evolution as the standard deviation of output growth. Indeed, when plotted in the same graph, their evolutions appear nearly identical.

In short, the decrease in output volatility appears to come from smaller shocks, rather than from a decrease in persistence of the effects of these shocks on output.

### **Back to the length of expansions**

Having estimated the process for output growth, we can return to the issue of the length of expansions. To do so, we proceed in two steps.

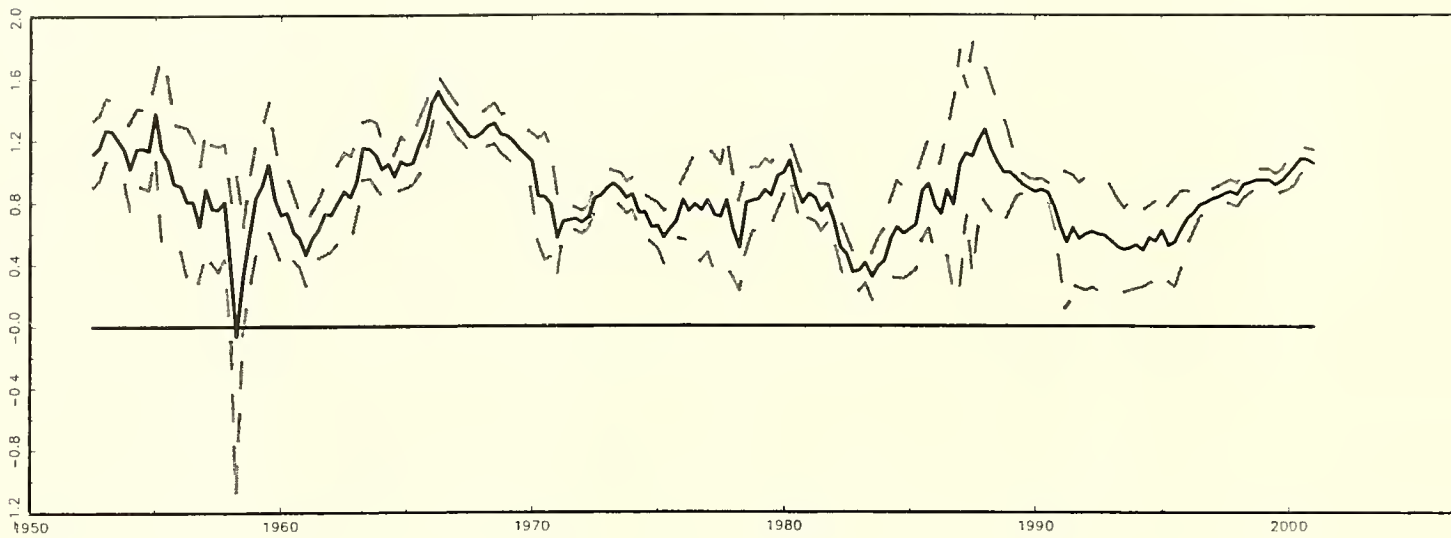
We estimate two processes, one for the period 1947:1 to 1981:4, the other for the period 1982:1 to 2000:4. We choose the split date to coincide with the peak of the cycle preceding the last two expansions. The intent of the split is to capture the major changes in the process between the start and the end of the sample.

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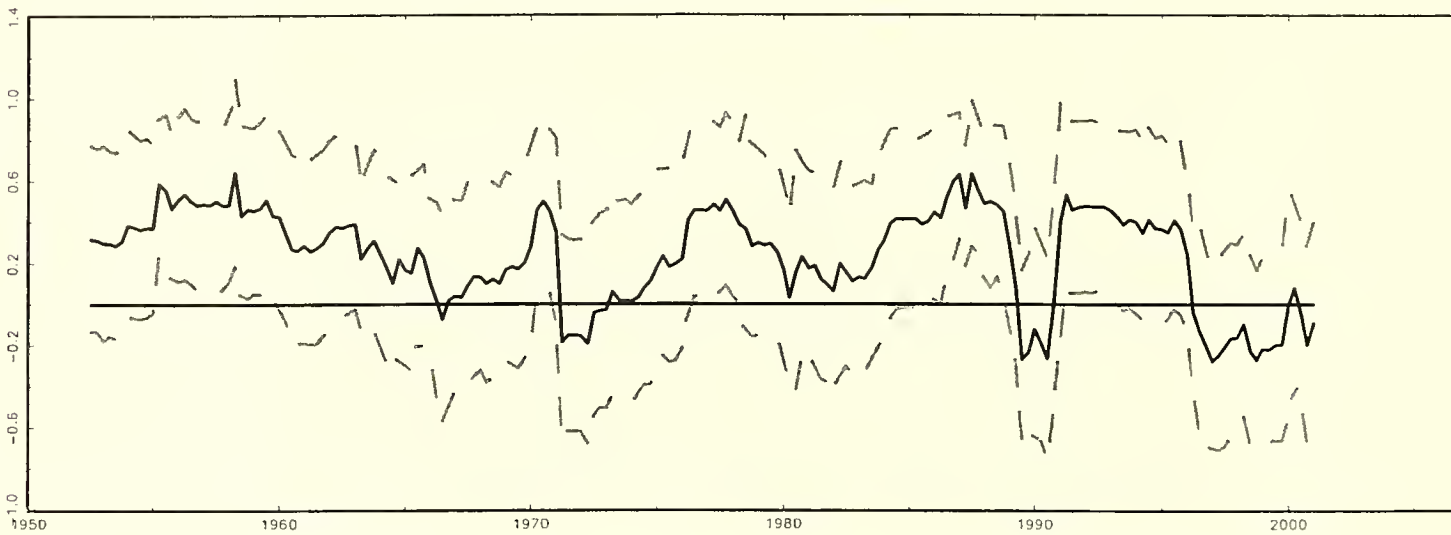
<sup>3</sup>A perhaps obvious point: Changes in the estimated AR(1) coefficient for the univariate representation of output growth do not imply a change in the dynamic structure of the economy. Output movements come from many underlying shocks, each with its own dynamic effects. At different times, different shocks may dominate the (short) subsample used for estimation, leading to different estimated univariate dynamics of output.

Figure 2

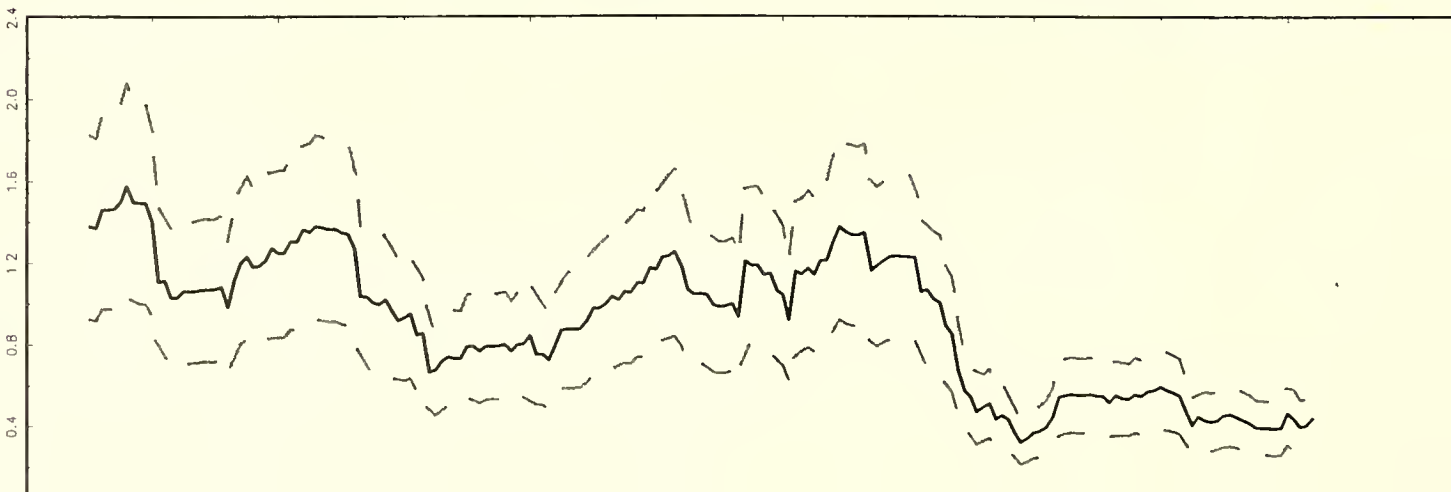
Rolling mean growth rate



Rolling ar(1) coefficient



Rolling standard deviation of residual



The two estimated equations are given by:

$$47:1 \text{ to } 81:4 \quad (\Delta y_t - 0.87) = 0.31(\Delta y_{t-1} - 0.87) + \epsilon_{Yt} \quad \sigma_\epsilon = 1.12$$

$$82:4 \text{ to } 00:4 \quad (\Delta y_t - 0.85) = 0.48(\Delta y_{t-1} - 0.85) + \epsilon_{Yt} \quad \sigma_\epsilon = 0.56$$

Using the first estimated equation, we generate a sequence of 100,000 observations for output growth, based on draws of the shocks from a normal distribution. Following a long tradition of approximating NBER dating by a simple rule, we define the beginning of a recession as two consecutive quarters of negative growth, and the beginning of an expansion as two consecutive quarters of positive growth following a recession. We compute the mean and median lengths of expansions in the sample of 100,000 observations. We then do the same using the second estimated equation.<sup>4</sup>

The results are shown in Table 1. The estimates are 17 and 13 quarters for the mean and median expansion length for the first subsample; 51 and 35 quarters for the second subsample. These means compare to an actual mean expansion length of 19 quarters for 1950:1 to 1981:4 (with recessions being defined with the same rule as in the simulation, not by NBER dating), and of 36 quarters for 1982:1 to 2000:4 (but with the second expansion not having ended yet). In other words, the differences between the two estimated

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<sup>4</sup>Note that the average length of expansions is a very non-linear function of the underlying parameters of the AR process. By construction, an expansion ends when a recession starts; under our definition of a recession, this requires two consecutive quarters of negative growth. The probability of such an event depends non linearly on the average growth rate, the standard deviation of the residual, and the AR coefficient. If, for example, the standard deviation is far below the average growth rate, small changes in the standard deviation will have little effect on the probability of a recession. If it is closer, the same small changes will have a substantial impact on the probability of a recession, and in turn on the length of expansions.

autoregressive processes account well for the increase in expansion length from the first to the second sample.

To show which parameter changes are responsible for this increase, we then show the results of switching either the mean, or the AR(1) coefficient, or the standard deviation of the shocks, across the two samples.

Not surprisingly, given that the growth rates are nearly the same in the two samples, switching them has no effect on the length of expansions. Switching the AR coefficients leads to shorter expansions in the first subsample (because the effect of a negative shock on output growth is now more persistent, making it more likely that output will decrease for two quarters in a row), longer in the second subsample. But nearly all the action comes from switching standard deviations. If the standard deviation had remained the same as in the first subsample, the mean length of expansions would now be only 14 quarters, the median 11 quarters. In short, it is the large decrease in the standard deviation of output shocks which is at the root of the two long expansions we have just experienced. And unless this changes, expansions are likely to be much longer in the future than they were in the past.

Table 1. Mean and median length of expansions (quarters)

	1947:1 to 1981:4	1982:1 to 2000:4
	mean/median	mean/median
Simulated	17/13	51/35
(Actual)	(19/15)	(36/—)
Switching:		
Growth rates	17/12	55/38
AR coefficients	15/11	83/55
$\sigma'_\epsilon s$	99/67	14/11

## 2 Are recessions special?

There is a widespread view of recessions and of output volatility under which the estimation and the exercise we carried out in the previous section is largely tautological at best, misleading at worst. According to that view, recessions are largely the result of infrequent large shocks—indeed sufficiently large and identifiable that they often have names: the first and second oil shocks, the Volcker disinflation and so on. Under that view, these shocks dominate output volatility, and there is no great mystery in the measured decline in output volatility: We just have not had large shocks over the last two decades.<sup>5</sup>

To see whether this is indeed what has been going on, we explore two approaches.<sup>6</sup> In the first, we look at what happens to the evolution of our measure of volatility if we simply exclude recessions from the sample. In the second, we look for signs of large shocks, and associated skewness and kurtosis, in the relevant distributions. Both approaches yield similar conclusions. The measured decline in output volatility is not due to the absence of large shocks over the last twenty years. What it captures instead is the decline in the volatility of “routine” quarter-to-quarter changes in GDP growth.

If the decline in volatility simply reflected the absence of large negative shocks and associated recessions, excluding recessions would then eliminate our findings. Indeed, excluding recessions from the sample is clearly too strong a correction under our null hypothesis. It corresponds to eliminating

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<sup>5</sup>This view was forcefully communicated to us by the editors of the Panel at the start of this project.

<sup>6</sup>recessions often come with unusually large negative realizations of the shocks also follows from the definition of the recession, and the fact that the distribution of shocks, conditional on being in a recession, implies a higher probability of large negative shocks.

large negative realizations just because they happen to be large and negative. But, if this overly strong correction still shows a decrease in volatility, it makes for convincing evidence. And this is indeed the case. To implement this approach, we re-estimate the same rolling regression as we did earlier, but allowing for the presence of a dummy variable taking the value of one in each of the quarters of an NBER dated recession. The resulting time series for the estimated standard deviation of the residual is plotted in Figure 3 (as the solid line), together, for ease of comparison, with the standard deviation obtained without recession dummies (the series shown in Figure 1 earlier, and plotted here as the dotted line).<sup>7</sup>

The results are quite clear. Output volatility is indeed lower in recessions (by construction). But the general evolution is very similar, with a clear trend downwards, from roughly 1.2 at the start of the sample, to 0.4 at the end.

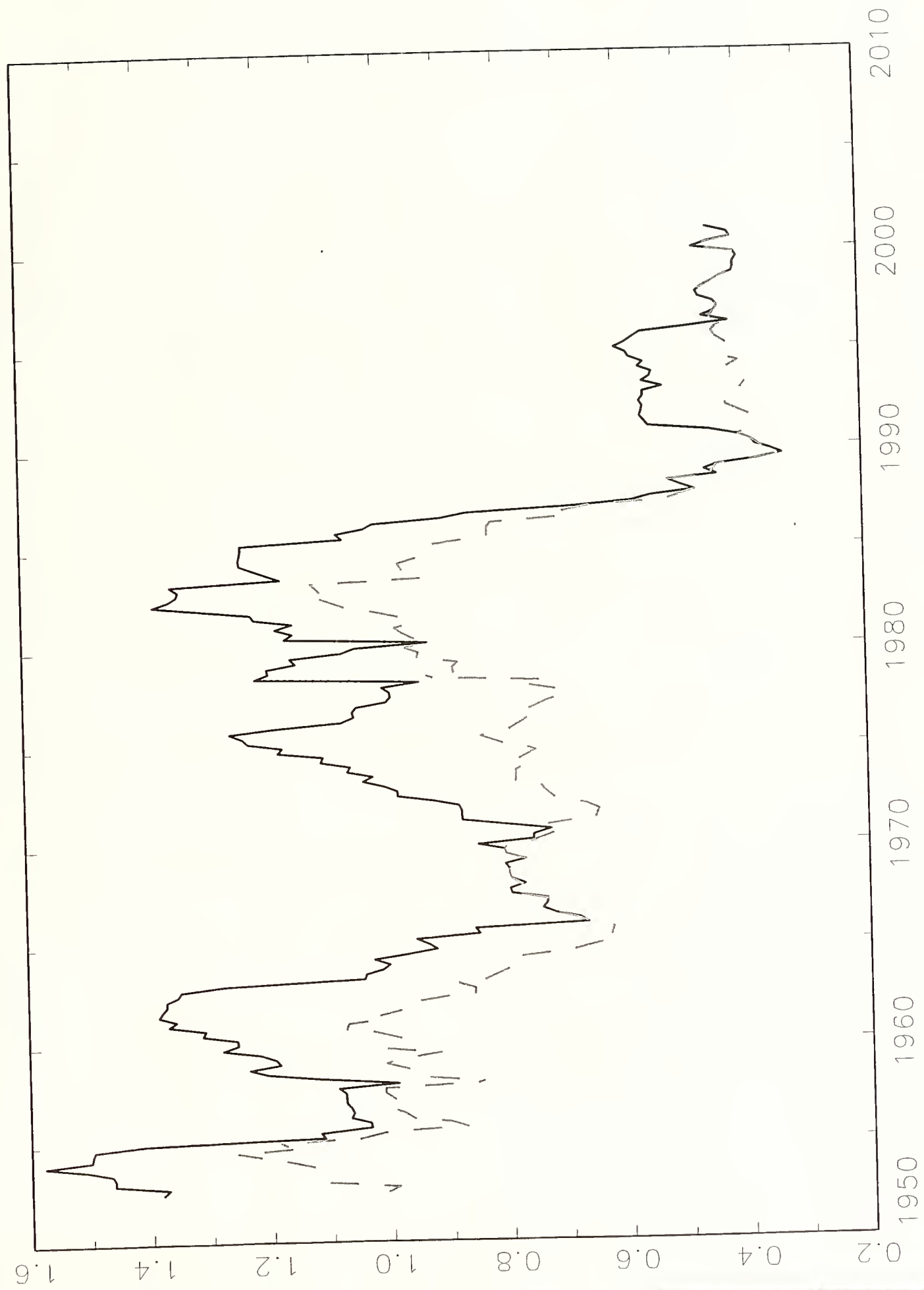
The other approach is to actually look for signs of infrequent, large, shocks. For example, under the hypothesis that the economy is subject to two types of shocks, frequent and small on the one hand, infrequent and large on the other, we would expect the distribution of output growth to exhibit either skewness (if large infrequent shocks are typically negative), or kurtosis (if large infrequent shocks are equally likely to be positive or negative), or both. Other, more complex, models of recessions have similar implications. While, by the Wold representation theorem, we know that even these models are still consistent with the linear representation given by (1.1), the residuals are likely also to exhibit either skewness or kurtosis.<sup>8</sup>

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<sup>7</sup>Introducing a dummy for recessions can be thought of a way of allowing for a lower mean growth rate in recessions. In this sense, this estimation is in the spirit of the Markov switching process estimated by Hamilton [1989] for U.S. GDP.

<sup>8</sup>Take, for example, the idea that serial correlation of output is higher in expansions

Figure 3. Rolling standard deviation, with/without recession dummies



This suggests looking at the evolution of skewness and kurtosis of  $\epsilon$ , the residual obtained from estimation of (1.1). The results are shown in Figure 4. Each point represents the estimate of skewness (top panel) or excess kurtosis (bottom panel) of the residual from estimation of an AR(1) process over the current and previous 19 quarters. Each of the two panels also gives the standard 95% confidence band for the hypothesis that each equals zero.

The two panels yield similar conclusions. Except for a brief period during the 1980 recession, there is little evidence of either significant skewness or kurtosis.<sup>9 10</sup>

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than in recessions, clearly a non linear feature. Capture this by the assumption that output growth is a two-state Markov process, with a high probability that output growth remains high if initially high, and a low probability that output growth remains low if initially low. It is easy to show that this Markov process will have an AR(1) representation given by (1.1), with the distribution of the residual skewed so that most residuals are small and positive but with a long negative tail associated with recessions.

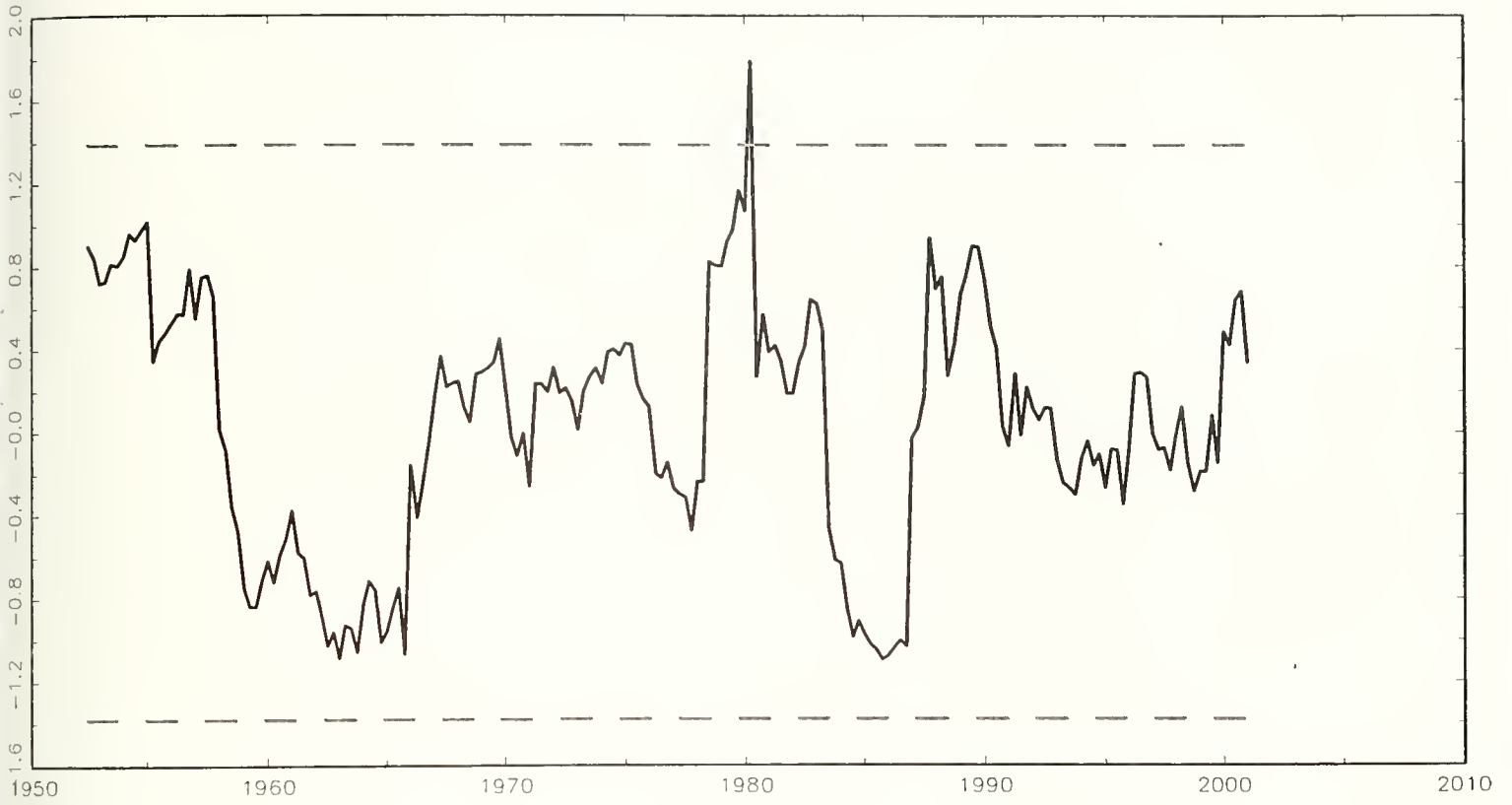
<sup>9</sup>Under the assumption that large shocks are indeed infrequent, the use of a short window (20 quarters) implies that there are many subsamples during which no large shock occurs. Those subsamples will not show evidence of skewness or kurtosis. But we would expect many or most recessions to be associated with measured skewness or kurtosis. This does not appear to be the case. Nor do we see more evidence of skewness or kurtosis if we use a longer window. Over the sample treated as a whole, there is indeed evidence of significant kurtosis, but this appears simply to be due to the decrease in the standard deviation over time (The distribution of draws from a set of normal distributions with different variances will exhibit kurtosis.)

<sup>10</sup>Other evidence that skewness and kurtosis are not important here is that the expansion length simulation results presented in the previous section are roughly unaffected if we draw shocks by sampling with replacement from the estimated residuals rather than from

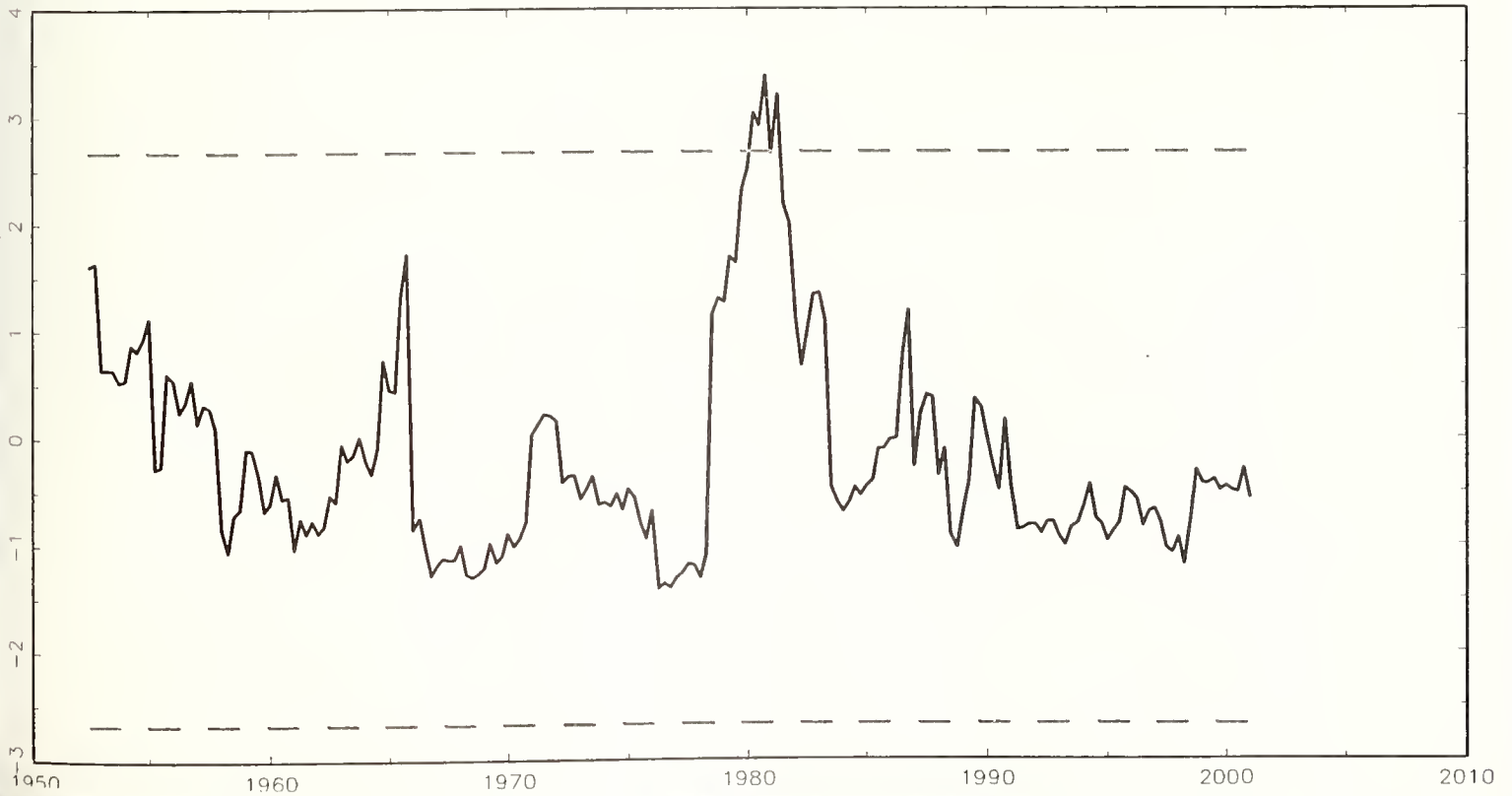


Figure 4

Rolling regression skewness



Rolling regression excess kurtosis



We have explored other approaches. Following Blanchard and Watson [1986], we estimated a specification in which the output shock is assumed to be the sum of two underlying shocks, one drawn every period from a normal distribution, the other equal to 0 with probability  $(1 - p)$ , and drawn from a normal distribution with larger variance, with probability  $p$ . We could not reject the hypothesis that  $p$  was equal to zero, and could not find evidence of a decrease in  $p$  over time. In other words, we could not find evidence that the decrease in output volatility has been due to a decrease in the likelihood of large shocks over time.<sup>11</sup>

### 3 Output volatility and inflation

Having established the basic fact, we now turn to its interpretation. There are at least two ways to look at the evolution of output volatility in Figure 1—or equivalently, at the evolution of the standard deviation of the residual in Figure 2, as the two are nearly identical.

The first, which we have implicitly relied on until now, is to see the evolution as a trend decline, temporarily interrupted in the 1970s and early 1980s. This interpretation is shown graphically in the top panel of Figure 5, which reproduces the evolution of the standard deviation of output from Figure 1, and draws in addition an estimated exponential trend over the period.

The second, which has been suggested in a number of recent papers (in particular McConnell and Perez-Quiros [2000]) is, instead, of a step decrease

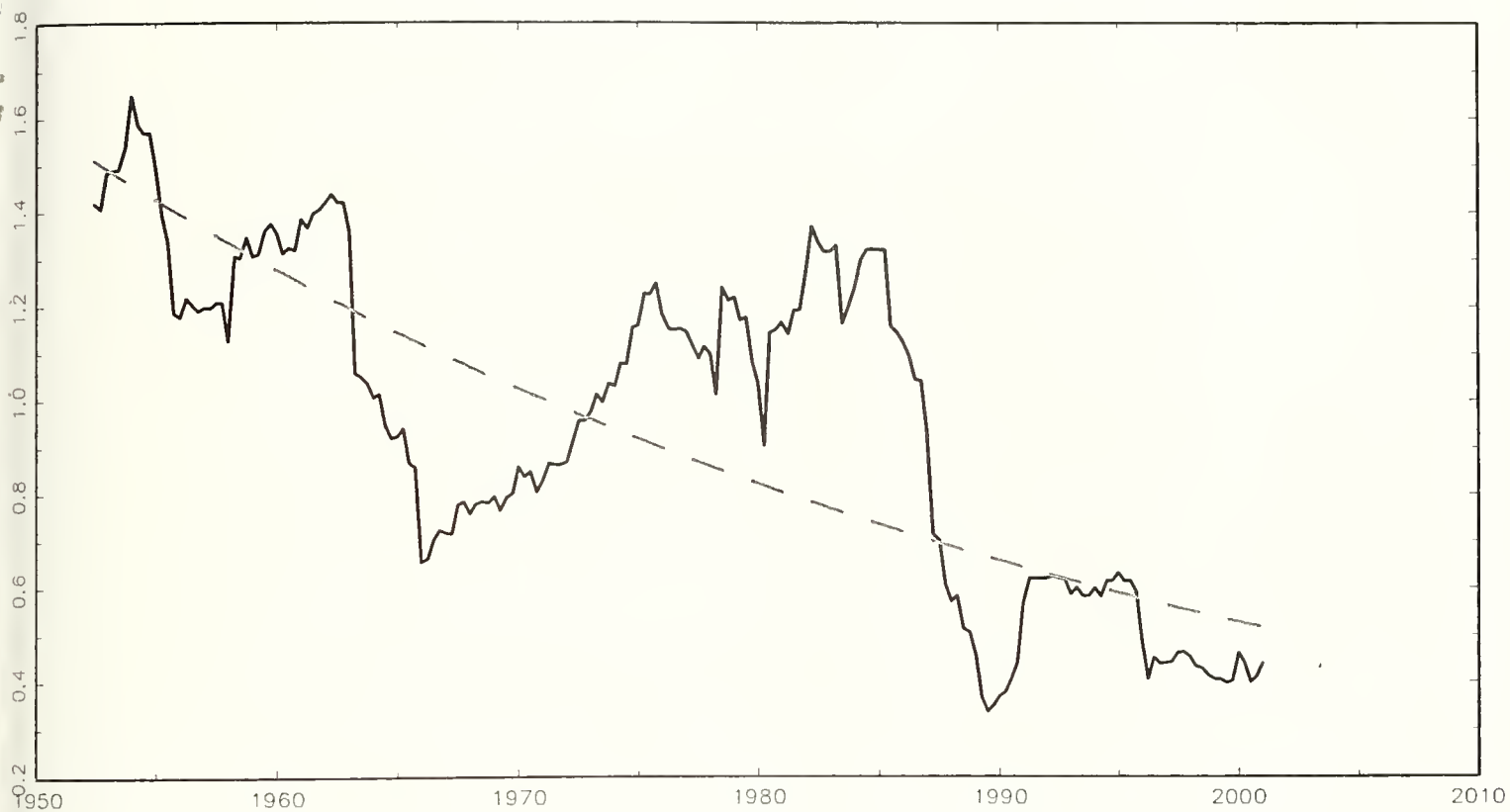
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a normal distribution—as we did in our stochastic simulations earlier.

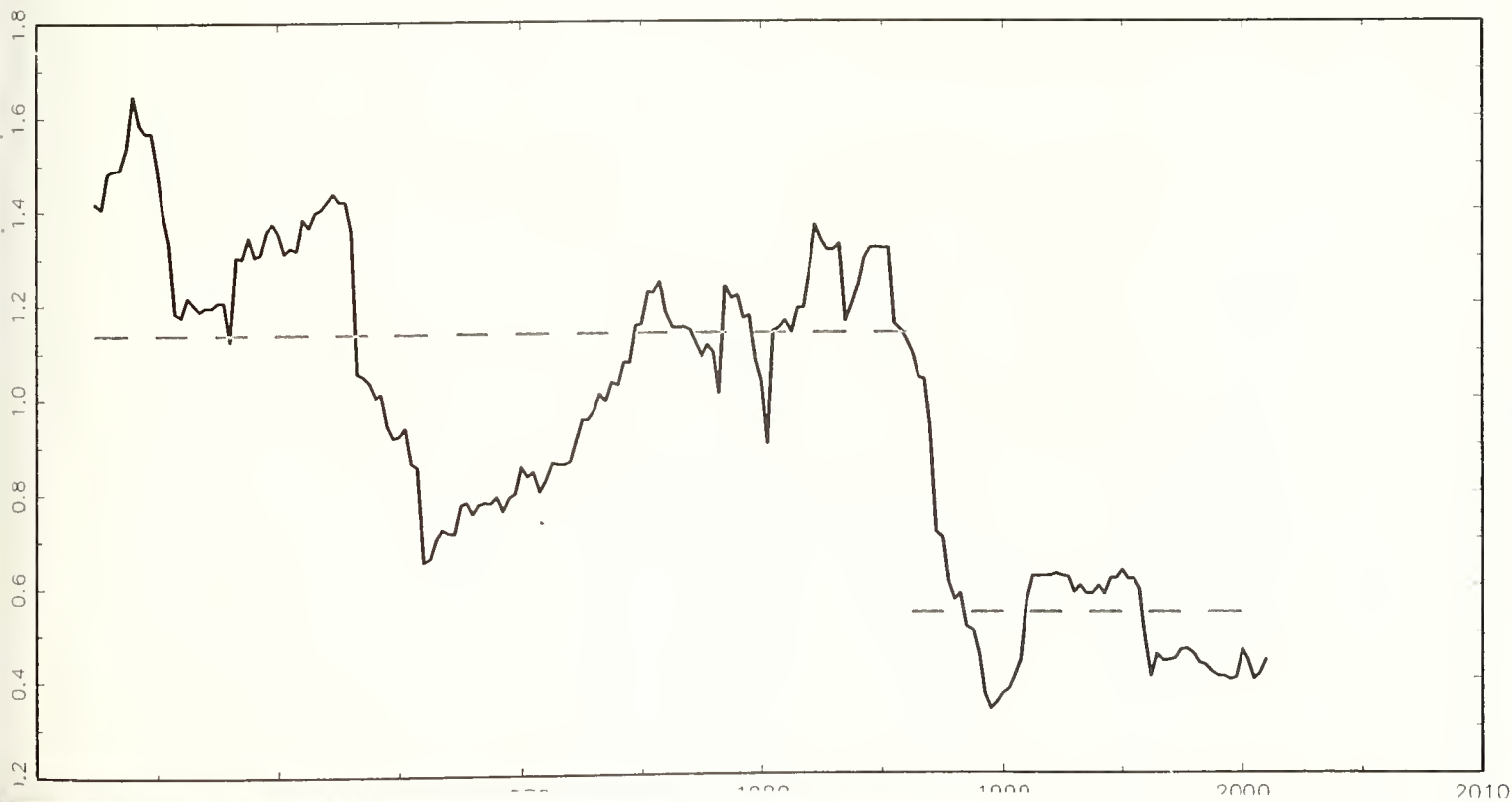
<sup>11</sup>One hypothesis is that there are large shocks, but their effects appear over a few quarters, making them more difficult to detect. If this were the case, the results of our exercise would be very different if we were to use lower frequency data. In fact, the results are nearly identical when using annual rather than quarterly data.

Figure 5: Trend decline or break in volatility?

Log linear time trend



Break in 1986:1



some time in the early to mid-1980s. This interpretation is shown graphically in the bottom panel of Figure 5, which shows how an estimated step function can also fit the general evolution of volatility. The step function is drawn on the assumption of a step decline in 1986:1. The more careful econometric work of McConnell et al, estimating rather than assuming the break date, finds a slightly earlier date, 1984:1, as the most likely break point.<sup>12</sup>

This second interpretation suggests looking for factors in the economic environment which changed around the mid-1980s. Plausible candidates are an improvement in the conduct of monetary policy (as argued for example by Taylor [2000]) , or changes in inventory behavior (as argued for example by Kahn et al. [2001].)

Under the first interpretation however, which we shall argue is more likely to be the right one, one needs to look for two sets of factors. First, the factors behind the underlying trend decline over the last 50 years.<sup>13</sup> Second, the factors behind the interruption of the trend in the 1970s. Put another way, the focus shifts from what happened in the 1980s (to explain the step decline in volatility) to what happened in the 1970s (to explain the interruption of the trend for a bit more than a decade). This is the interpretation we prefer, and the route we follow in the rest of the paper.

### **Inflation and inflation volatility**

That the 1970s were different is not very controversial. The U.S. economy was affected by major increases in the prices of raw materials, including oil. Inflation increased, to return to a lower level only after the disinflation of

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<sup>12</sup>The difference comes from our use of a rolling window to capture volatility. A decline in 1984:1 will not necessarily show up until enough earlier observations have dropped out of our window—something that happened around 1986:1.

<sup>13</sup>Or indeed over the past century, if one takes a longer view, informed by the evidence from earlier research on volatility since the late 1800s.

the early 1980s. That these shocks, and perhaps inflation itself, may have led to more output volatility does not seem implausible.

Figure 6 shows the relation between inflation and output volatility. The top panel plots output volatility (dotted line) against the 20-quarter rolling mean of the inflation rate (solid line)—with inflation measured using the GDP deflator. The bottom panel plots output volatility (dotted line) against inflation volatility (solid line), both constructed as 20-quarter rolling standard deviations. (All variables, including mean inflation, are measured at quarterly rates).

The temporary increase in output volatility in the 1970s and early 1980s is clearly correlated with the temporary increase with the level of inflation. Output volatility seems however more strongly related to the volatility than to the level of inflation. Simple regressions of output volatility on the level of inflation, inflation variability and an exponential time trend show all three factors to be significant, with the level and the variability of inflation playing roughly quantitatively similar roles, and the negative time trend remaining important and significant.<sup>14 15</sup>

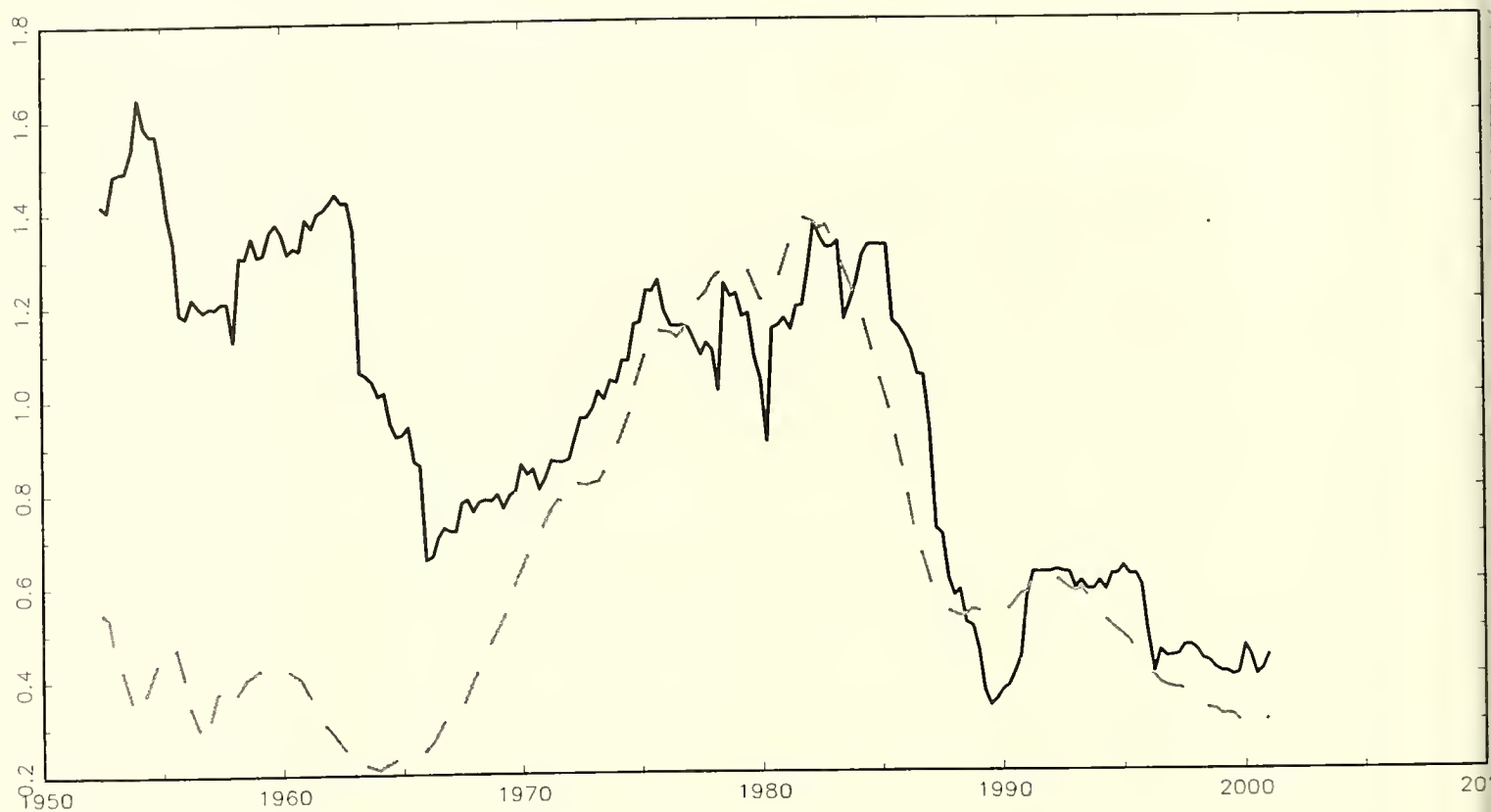
Correlation between inflation and output volatility does not imply however causality from inflation to output volatility. At least one plausible alternative is that the correlation reflects a common dependence of inflation and output volatility on third factors, such as the supply shocks of the 1970s.

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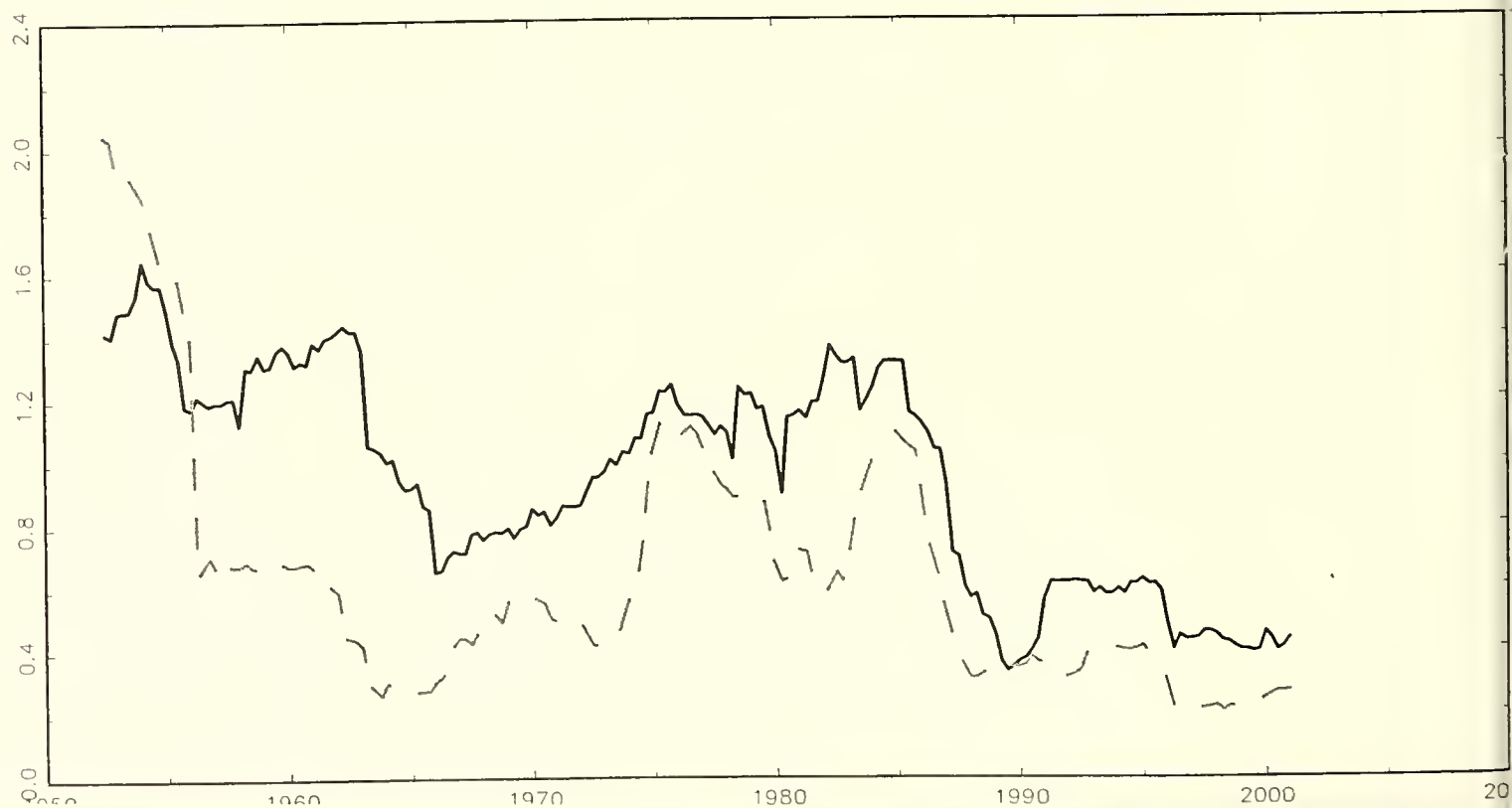
<sup>14</sup>One worry is that measurement noise in the decomposition of nominal GDP will create a spurious positive correlation between output and inflation volatility. But the results are very similar if we use the CPI, where the issue is likely to be less important.

<sup>15</sup>One problem with such regressions is the use of moving averages for standard deviations and means both on the left and right hand sides. Estimation of a potentially more appropriate GARCH model for output growth, allowing the variance of output shocks to be a function of inflation volatility, the inflation level, and a time trend yields very similar results.

Figure 6: Volatility of output and inflation  
Standard deviation of output and mean inflation



Standard deviation of output and of inflation



Here, international evidence can help:

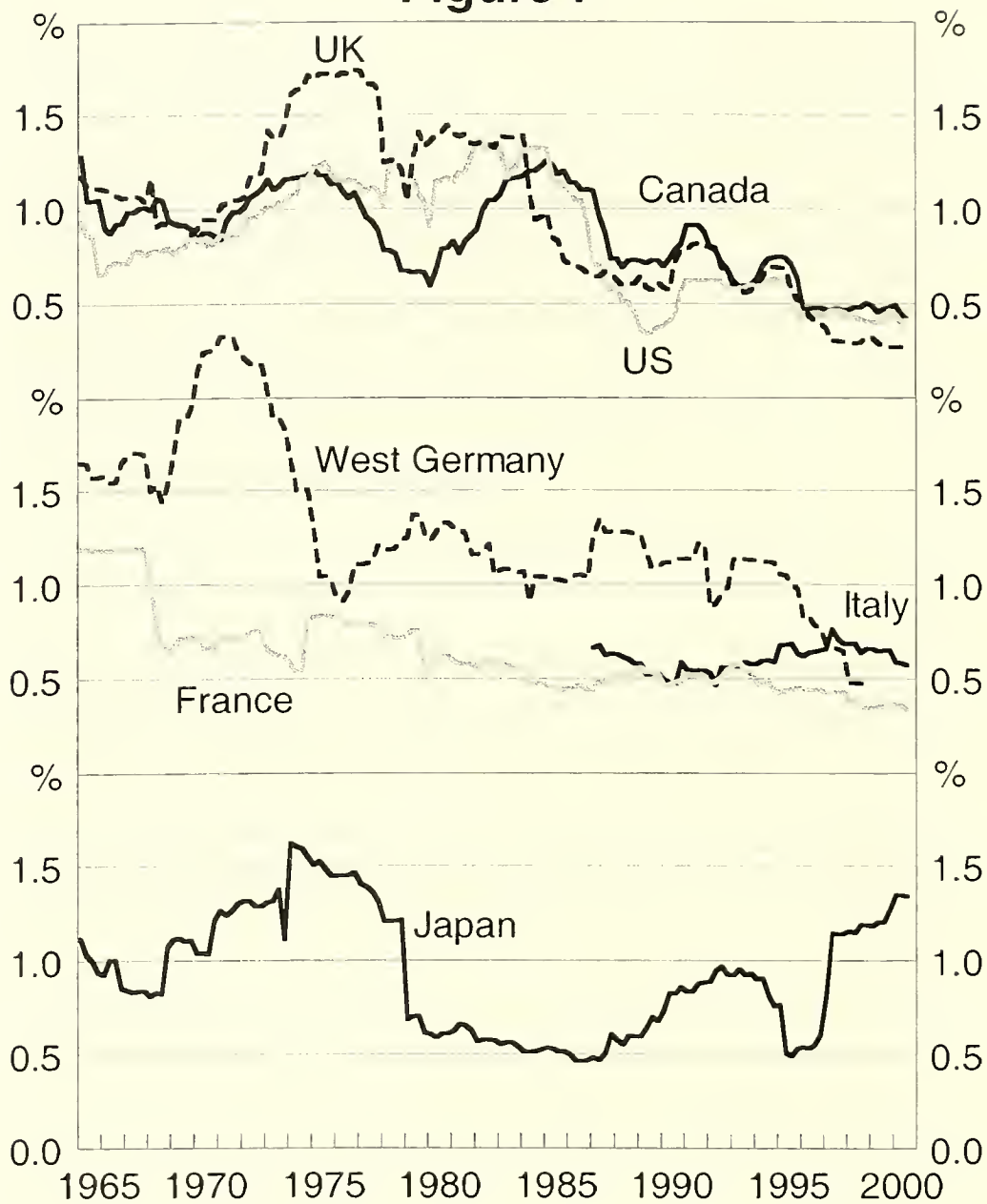
First, and obviously, it can tell us whether the US evolutions are representative of what happened to output volatility, and to the relation between output and inflation volatility elsewhere. But also, if we are willing to assume that the supply shocks of the 1970s were largely common across countries, then it gives us a way of controlling for their presence by treating them as fixed effects in a cross country panel regression. In other words, such a regression can help us establish the relation between output and inflation volatility, controlling for supply shocks. With this in mind, we now turn to the evidence from the G7 countries.

#### **A look at the other G7 countries**

Figure 7 shows the evolution of output volatility for the G7 countries. For clarity, we have grouped the countries in three panels. The top panel includes the United States, the United Kingdom, and Canada. The middle panel includes West Germany, France, and Italy. The bottom panel shows Japan. In each case, the measure of output volatility is the rolling standard deviation of output growth, using a window of 20 quarters. Because the data we have start only in 1960 (1982 for Italy), the different measures are available only from 1965:1 on (1987:1 for Italy), a shorter sample than the one used for the United States above.

The top and the middle panels show that six of the G7 countries have had roughly similar evolutions over the period. In all countries, the standard deviation of output has declined, from a range of 1.5% (for Germany) to a little below 1.0% (for the U.S.) in the early 1960s, to around 0.5% for all countries in the late 1990s. One of the striking characteristics of these two panels is indeed how similar the standard deviation of output growth is across these countries today. The general decline and convergence suggest the presence of common, long lasting, forces across countries. Looking more closely, however, there are also clear differences across countries, especially

# Figure 7





in timing. After the general increase of the early 1970s, the decrease in volatility has taken place earlier in Germany, later in Canada.

The only G7 country to have a clearly different evolution is Japan, shown in the bottom panel. After a decrease from the early 1960s to late 1980s, the standard deviation of output has increased in the 1990s, and is now higher than it was at the start of the sample. To the extent that this increase largely coincides with the long Japanese slump of the 1990s, it is tempting to search in that direction for an explanation. For example, a decrease in liquid assets by both firms and consumers may have led to stronger effects of cash flows on consumption and investment, leading to stronger multiplier effects of shocks on output. The floor on interest rates may have constrained monetary policy responses. We have not explored these hypotheses further in this paper, but we find the coincidence of the long slump and the increase in volatility intriguing, and potentially useful in learning what has happened in other countries.

Leaving Japan aside and focusing on the other six countries, we return to the relation between output volatility and inflation. To do so, we run the following panel regression;

$$\sigma_{yit} = \beta_i + \beta_t + a_1 \bar{\pi}_{it} + a_2 \sigma_{\pi_{it}} + \epsilon_{it} \quad (3.1)$$

where  $i$  refers to country, and  $t$  to time, so the  $\beta_i$ 's are country fixed effects, the  $\beta_t$  are time fixed effects,  $\sigma_y$  and  $\sigma_\pi$  are rolling standard deviations of output and inflation, and  $\bar{\pi}$  is a rolling mean of the inflation rate.

If the effects of the supply shocks of the 1970s on output volatility were indeed common across countries, then this specification will give us the relation between output and inflation volatility controlling for supply shocks. The assumption is probably too strong however: The effects of supply shocks were different across countries, and these differences may well have been associated with different evolutions of both the level and the volatility in-

flation. In this case, the coefficient on inflation will still pick up some of the effects of supply shocks. Nevertheless, even in this case, this cross country specification is an improvement over the U.S. regression (in which we could not introduce fixed time effects) presented earlier.<sup>16</sup>

Estimation yields coefficients of  $a_2 = 0.67$  with a t-statistic of 13.7, and  $a_1 = -0.02$ , with a t-statistic of -0.7. Thus, it is inflation volatility, rather than the level of inflation which appears to matter, and to matter strongly. The best way to summarize the implications of the regression is through a set of graphs, which are given in the three panels of Figure 8:

- The top panel gives the actual and the fitted values of output volatility for the United States (dropping  $\bar{\pi}_{it}$  from the panel regression—nothing is changed by this). The conclusion to be drawn is that the panel specification does a good job of fitting the U.S. evolution.

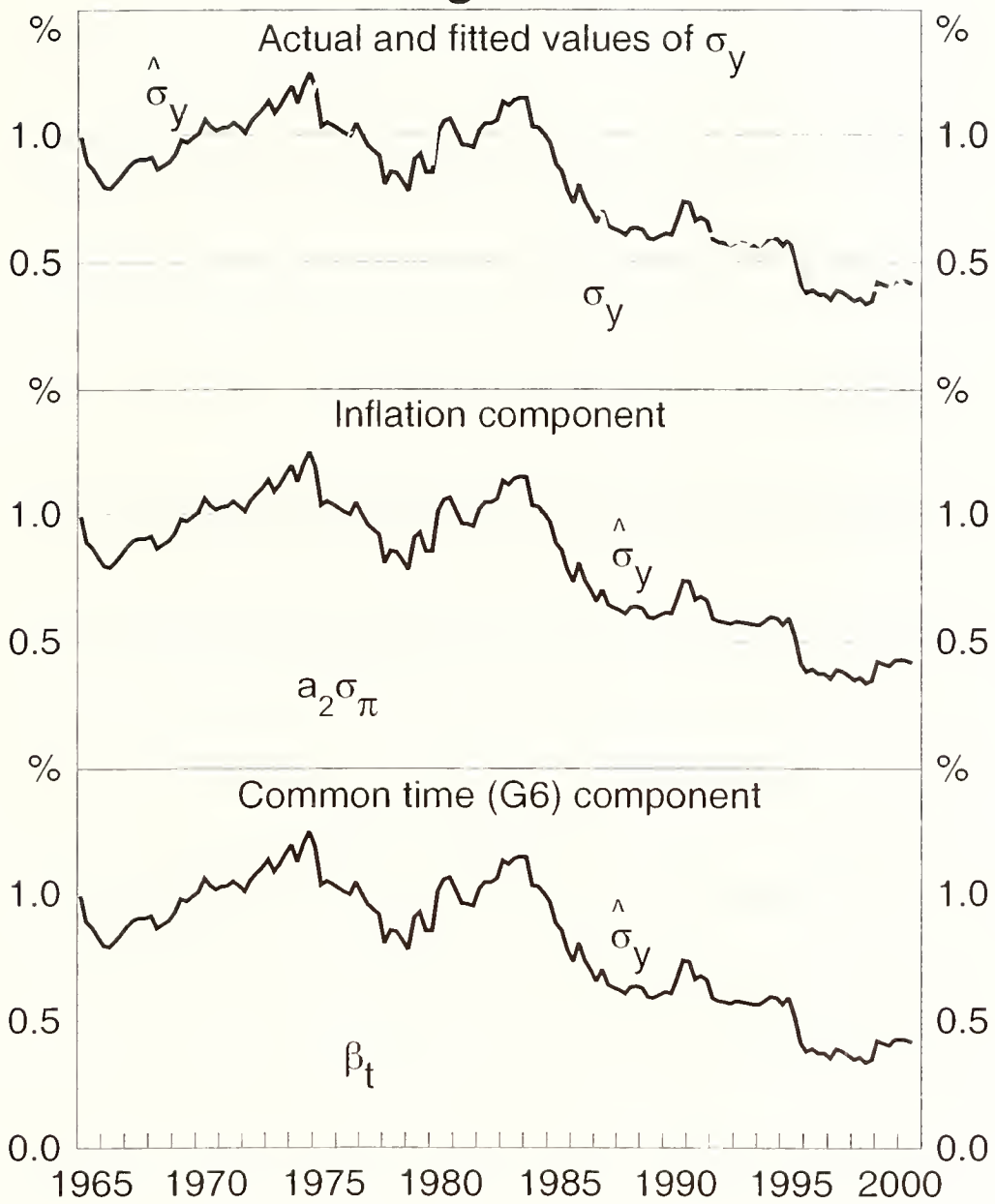
The other two panels show how much of the evolution comes from movements in inflation, and how much is due to the common time components:

- The second panel gives the evolution of the fitted value of output volatility (repeated from the first panel), together with the evolution of the inflation component,  $a_2\sigma_{\pi_{it}}$ . The panel makes clear that the increase in inflation volatility accounts for the reversal in trend from the early 1970s to the early 1980s.

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<sup>16</sup>Note that, even under the assumption of common supply shocks, this specification does not resolve other potential identification problems, such as the possibility that the relation between output and inflation volatility reflects causality from output to inflation volatility (through the response of monetary policy), or a dependence on other third causes, such as an improvement in the conduct of monetary policy leading to lower output and inflation volatility.

# Figure 8



- The third panel gives the evolution of the fitted value of output volatility (again repeated from the first panel), together with the evolution of the common time component,  $\beta_t$ . This suggests a steady underlying trend decrease from 1960 on.

In short, this decomposition suggests a trend decrease in volatility, temporarily interrupted by an increase in inflation volatility. Under that interpretation, the sharp decline in output volatility in the 1980s appears to be mostly the result of a sharp decline in inflation volatility.

To get a better understanding of both the trend decrease and the temporary reversal in output volatility, the last section goes one level down, and looks at the evolution of the individual components of GDP.

#### 4 A look at the components

In his 1960 Presidential address to the American Economic Association, Arthur Burns (Burns [1960]) argued that a trend decline in output volatility was indeed under way. Composition effects and the steady shift to services, improvements in capital markets and the increasing ability of consumers to smooth consumption in the face of variations in income, the increase in the income tax and stronger automatic stabilizers, all led, and, he argued, would continue to lead, to more economic stability.

He was clearly right about the trend. Was he right about the channels? This section makes a first pass at the answer. From a statistical accounting point of view, one can think of the volatility of output as depending on three sets of factors, the volatility of its components, their co-variation, and their relative weight. We look at all three in turn.

##### Volatility of output components

Take the standard decomposition of GDP by type of purchase and type of purchaser, consumption, investment, government spending, net exports

and inventory investment. Let each of these components, in real terms, be denoted by  $X_i$  so:

$$Y_t = \sum_i X_{it}$$

For each of the components, we consider two measures of volatility:

The first is the same as for GDP earlier, namely the rolling standard deviation of the rate of growth of  $X_{it}$ , which we denote by  $\sigma_{xit}$ . This measure makes little sense however for inventories and net exports which change signs and are frequently close to zero. Thus, we construct the rolling standard deviation of growth for consumption, investment, and government spending only.<sup>17</sup>

The second measures the volatility of a variable commonly called the “growth contribution” of each component, which adjusts for the share of the component in GDP. A very volatile component may have little effect on overall output volatility if it accounts for a small share of GDP. The variable is defined as  $\Delta X_{it}/Y_{t-1}$ , and our measure of volatility is once again the rolling standard deviation. Note that this measure is well defined for all components of GDP regardless of whether they change sign or are close to zero. Note also that the variable can be rewritten as  $(\Delta X_{it}/X_{it-1})(X_{it-1}/Y_{t-1})$ , so, if the share is stable at high frequency, the standard deviation will be roughly equal to the share of the component of GDP, times the standard deviation of the component’s growth rate. For both volatility measures, the window we use to compute standard deviations is 20 quarters. Rates of change are quarterly, not annual rates.

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<sup>17</sup>In parallel with our exploration of GDP, we have estimated AR processes for each component. The general conclusion is the same as for GDP. For the most part, the decrease in volatility comes from the decrease in the volatility of the shocks than from a change in dynamics. We do not present the results here.

The evolutions are plotted in Figures 9 and 10. The first measure is given by the solid line, and the scale is on the left axis. The second is given by the dotted line, with the scale on the right axis. Note that the two lines move largely together at high frequency, reflecting the stability of the shares.

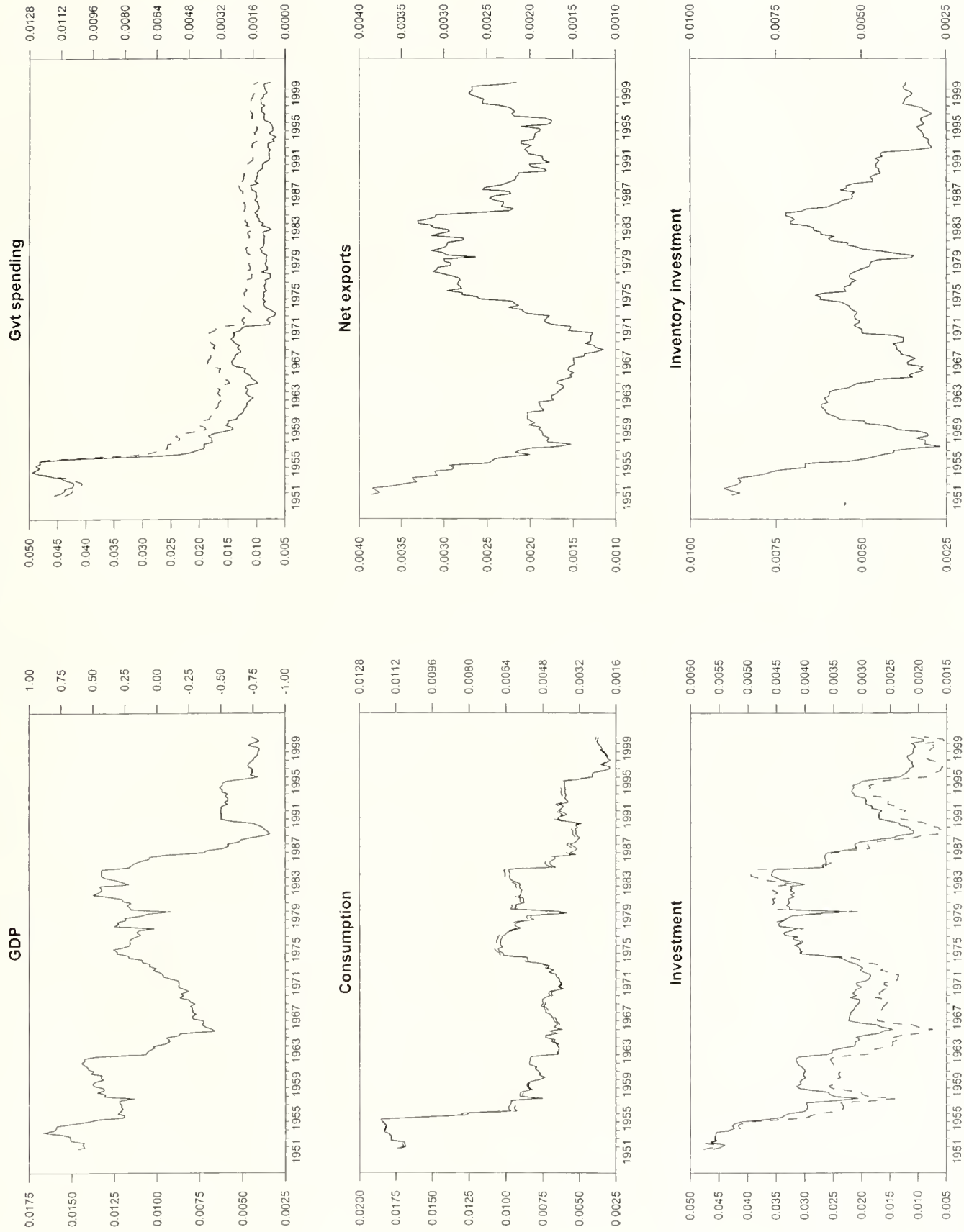
From Figure 9, we draw the following conclusions:

- Volatility of government spending (and of fiscal policy in general) was very high during the Korean war. It rapidly went down in the 1950s, and has remained low ever since.
- There is no clear trend in the volatility of net exports. There is also no clear trend in the volatility of inventory investment, although volatility has been low in the 1990s (this together with the change in correlation shown below, suggests a recent change in the behavior of inventory investment.)
- Most of the decrease in overall volatility can be traced to a decrease in the volatility of consumption and investment. After a large decrease in the 1950s, consumption has continued to decrease, from about 0.75% in the 1960s to 0.30% in the late 1990s. The decrease in investment volatility has been more limited. The standard deviation of our second measure is nearly the same in the late 1990s as it was in the 1960s.

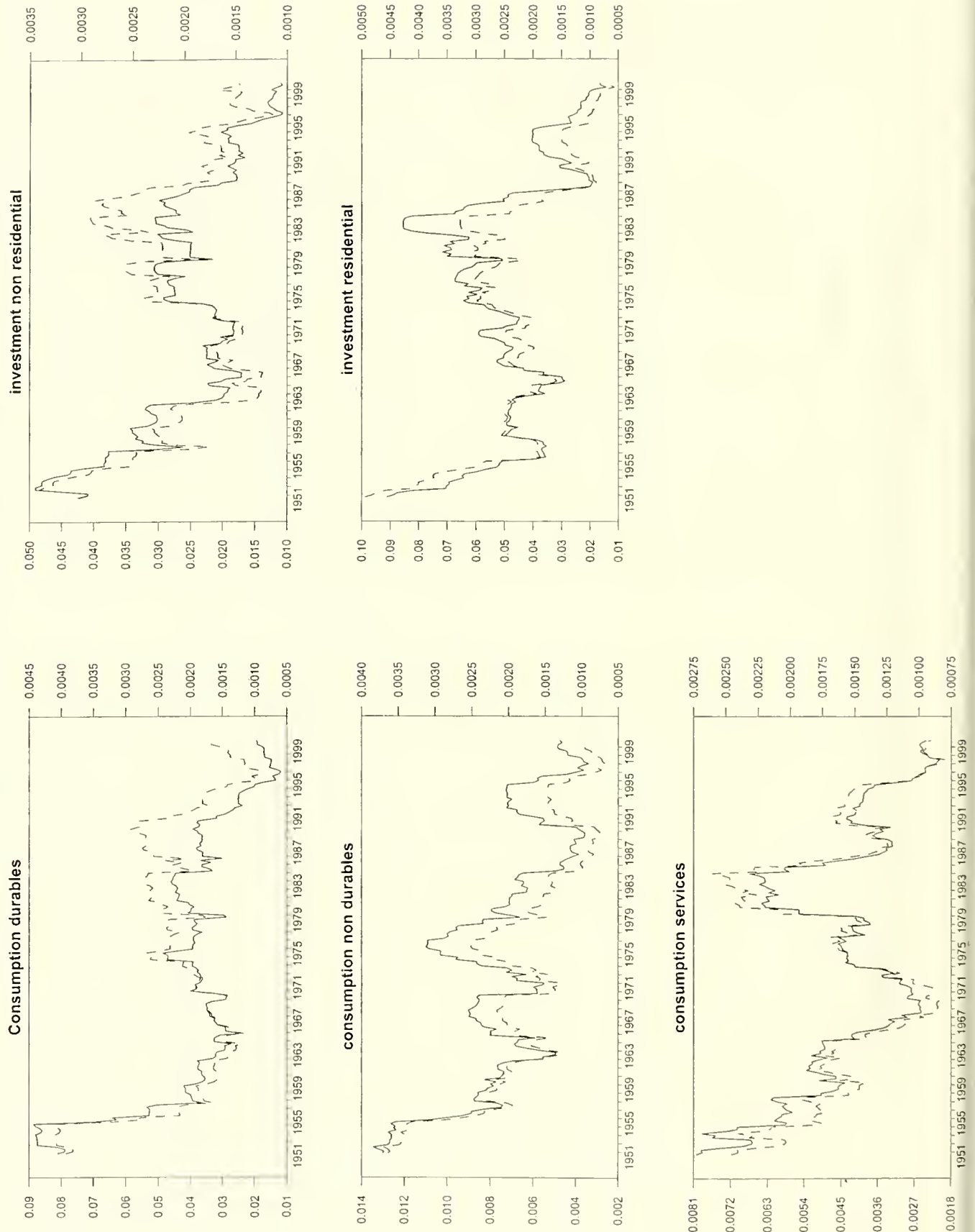
Given that much of the action comes from consumption and investment, Figure 10 goes one further step down and shows the evolution of the volatility of consumption and investment components.

- Relative declines in the volatility of all three components of consumption, spending on durables, on non-durables, and on services, are roughly similar. Their timing is slightly different, with much of the trend reversal in consumption in the 1970s and early 1980s coming from consumption of services.

# Figure 9. Standard deviations, $DX/X$ , $DX/Y$



# Figure 10. Standard deviations, DXIX, DX/Y





We think these are slightly surprising findings. One might have expected improvements in financial markets to lead consumers to choose a smoother consumption path, thus leading to smoother consumption of services and non durables. But one would also have expected an improved ability to borrow and lend to lead to a stronger stock-flow adjustment for purchases of durables, and thus potentially to more volatility of durable purchases. This does not seem to be the case in the data.

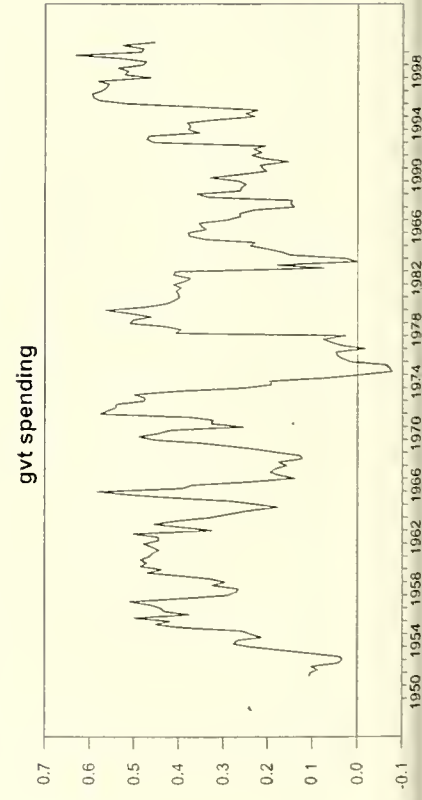
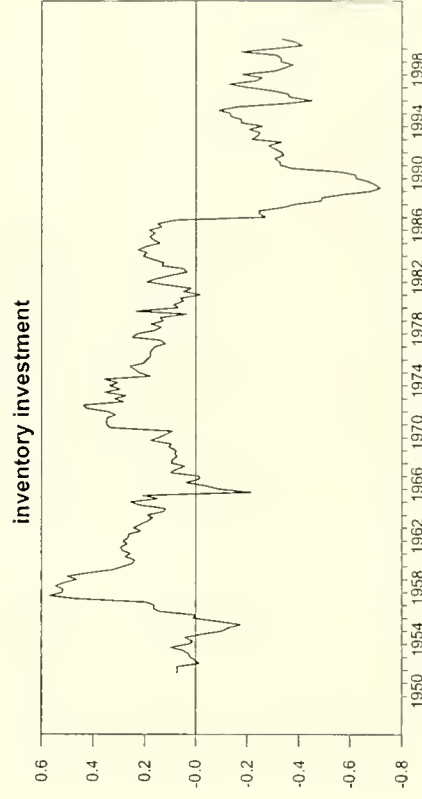
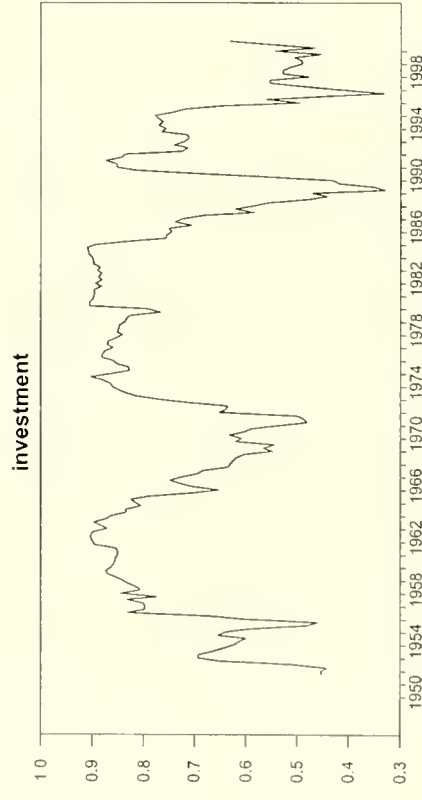
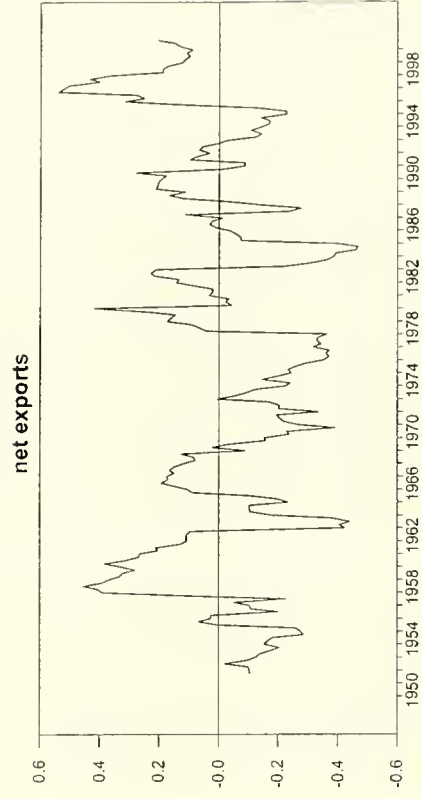
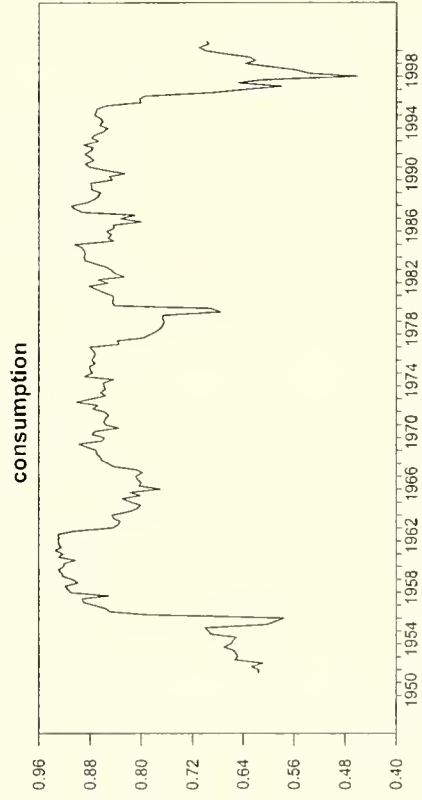
- The two series for investment volatility exhibit quite different evolutions. Non residential investment shows a steady decline, and a limited increase in the 1970s. Residential investment shows a steady increase from the 1950s to the mid 1980s, and a sharp decrease after that. The sharp decrease corresponds to the elimination of interest rate ceilings on savings and loan institutions (the end of Regulation Q), making it a plausible candidate explanation.

### Correlations of output components

The standard deviation of output depends not only on the standard deviations of its components, but also on their correlations. To show what has happened, we construct the correlation of each component with final sales (i.e GDP minus inventory investment)—more specifically the correlation of  $\Delta X_{it}/Y_{t-1}$  with  $\Delta S_t/Y_{t-1}$ , where  $S_t$  is final sales. Again, we use a window of 20 quarters.

These evolutions are shown in Figure 11. The correlations change over time (as we would expect if the subsamples are dominated by different shocks, with different implications for the correlation between each component and final sales). But, except for one series, they do not show clear trends. The exception is the correlation between inventory investment and sales. Until the mid-1980s, inventory investment tended to move with sales,

# Figure 11. Correlation $DX/Y$ , $DS/Y$



leading to a higher variance of production than of sales—a fact studied at length by the research on inventory behavior. Since the mid 1980s, inventory investment has become countercyclical, leading to a decline in the variance of output relative to sales. This fact, which has been examined by Kahn et al. [2001], must have come from a change in the inventory management methods of firms. It is clearly one of the factors behind the decrease in output volatility in the 1980s, although only the last one in a long series of structural changes.<sup>18</sup>

### Composition effects

The composition of GDP has changed substantially over the last fifty years. The main three changes (at the level of disaggregation at which we are looking) are the increase in the share of (high volatility) fixed non residential investment, from 9.6% in 1950 to 13.8% in 2000, the decrease in the share of non durables consumption, from 36.9% to 20.1%, and the mirror increase in the share of (low volatility) consumption of services, from 20.8% to 39.3%.

To characterize the effects of composition on output volatility, a simple approach is to compute the volatility of a counterfactual series for output growth, using 1947 shares rather than current shares to weigh components. More specifically, we construct the counterfactual output growth series as follows. Write the rate of growth of output as:

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<sup>18</sup>There is a puzzle here as well: The change in correlation roughly coincides roughly with the introduction of “just in time” inventory management methods. These methods have led to lower inventory-to-sales ratios. It is not clear however why they should have led the correlation to change from positive to negative: Better tracking and forecasting of sales, and the ability to maintain a stable inventory to sales ratio should lead to more not less procyclical inventory investment...

$$(\Delta Y_t/Y_{t-1}) = \sum_i \Delta X_{it}/Y_{t-1} + \sum_j \Delta X_{jt}/Y_{t-1}$$

where the terms in the first sum are the terms which are always positive, and the terms in the second sum are the terms which change sign in the sample (net exports, and inventory investment). We can rewrite this expression as:

$$(\Delta Y_t/Y_{t-1}) = \sum_i \alpha_{it-1} \Delta X_{it}/X_{it-1} + \sum_j \Delta X_{jt}/Y_{t-1}$$

where  $\alpha_{it-1}$  is the share of component  $i$  at time  $t-1$ . Once again, constructing  $\Delta X_{jt}/X_{jt-1}$  does not make much sense for inventories and net exports as they are frequently around zero. Consequently, we treat them separately. We then construct the counterfactual series for output growth as:

$$(\Delta Y_t/Y_{t-1})^* = \sum_i \alpha_{i1947} \Delta X_{it}/X_{it-1} + \sum_j \Delta X_{jt}/Y_{t-1}$$

where  $\alpha_{i1947}$  is the 1947 share of component  $i$ . We then construct rolling standard deviations for actual and counterfactual output series. There is no need to present a figure, as the two series are nearly indistinguishable. The different changes in composition nearly offset each other, and the final values are within .05% of each other. Composition effects have little to do with the general evolution of output volatility over the last 50 years.

## 5 Conclusions

We have documented the long and large decline in output volatility over the last half-century. We have shown that this evolution does not have one, but

many proximate causes. Among them, the evolution of inflation volatility, up in the 1970s and early 1980s, down since then; a steady decrease in investment volatility, and even more so of consumption volatility; a decrease in the volatility of government spending early on. A change from procyclical to countercyclical inventory investment in the 1990s. Many questions remain however.

First, about the deeper causes of the decrease in volatility, from the role of policy—especially monetary policy—to the role of structural changes—especially changes in financial markets.

- Our findings suggest a complex role for monetary policy. On the one hand, the trend decrease in output volatility from 1950 on does not give much support for the idea that what we are seeing is primarily the result of a dramatic recent improvement in our conduct of monetary policy, of a Greenspan effect. On the other, the dramatic decrease in output volatility in the mid- 1980s can be interpreted in two ways, both of them related to monetary policy.

The first is that this decrease was indeed the result of smarter countercyclical monetary policy, leading to better output stabilization from the 1980s on. This explanation runs into a puzzle however. Given the lags in the effects of monetary policy on output, one would have expected better monetary policy to show up primarily as shorter lived effects of shocks on output, and thus as a decrease in the AR(1) coefficient in the univariate autoregressive representation. There is no evidence that this has been the case.<sup>19</sup>

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<sup>19</sup>A more sophisticated argument is that, despite the lags in monetary policy, better policy might have reduced the variance of measured output shocks is leading agents to expect shorter-lived effects of the underlying shocks on GDP, and thus to react less to these shocks in the first place. But, even in this case, better policy should be reflected in

The other is that it was associated with—and may have been largely caused by—the decrease in inflation volatility which occurred around the same time. But even this second interpretation implies a role for monetary policy. The increased inflation stability is likely to have been due, in large part, to better monetary policy.

- Our findings also suggest a role for improvements in financial markets in reducing consumption and investment volatility. But, here again, the argument is not straightforward. On theoretical grounds, it is not obvious that more efficient financial markets should lead to lower consumption volatility. While, for given interest rates, they plausibly lead to a decrease in the volatility of consumption services and non durables, they also allow consumers to adjust faster to their desired stock of durables, leading, other things equal, to more volatility of spending on consumer durables. The same argument applies to investment. The evidence is however of a decrease in volatility in all components of consumption and investment.
- The issue of the relative role of monetary policy and financial market improvements in reducing output volatility is a fascinating one. In that respect, the evolution of Japan in the 1990s is both intriguing and inconclusive. As we saw, output volatility increased substantially in Japan in the 1990s. But was it due to monetary policy, or to changes in financial markets (or to something else)? The answer is far from obvious. Monetary policy, both current and anticipated, was clearly limited by the constraint that interest rates be non negative—the liquidity trap. And, because of the problems of banks, intermediation was clearly disrupted. Only a more disaggregated examination will

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both a smaller variance of measured output shocks, and in shorter lasting effects of shocks on output—thus in a decrease in the AR(1) coefficient.

help attribute blame.

Second, about the implications of our findings.

- We feel reasonably confident in predicting that the increase in the length of expansions is here to stay (This is not a prediction that the United States will not go through a recession in the near future, nor is it a statement that the New Economy has eliminated the business cycle...): The decrease in output volatility appears sufficiently steady and broad based that a major reversal appears unlikely. This implies a much smaller likelihood of recessions.
- Lower output volatility suggests lower risk, and thus changes in risk premia, in precautionary saving, and so on. Interestingly, the decrease in output volatility has not been reflected in a parallel decrease in asset price volatility. The last figure of this paper, Figure 12, plots the evolution of output and of stock market price volatility, the second being measured as the rolling standard deviation of the rate of change of the Dow Jones index. As documented by others, there is little evidence of a trend in Dow Jones volatility.<sup>20</sup>
- And, obviously, ultimately what is important is not aggregate risk, but the risk facing individuals. We do not know what has happened to the volatility of idiosyncratic shocks during the period.

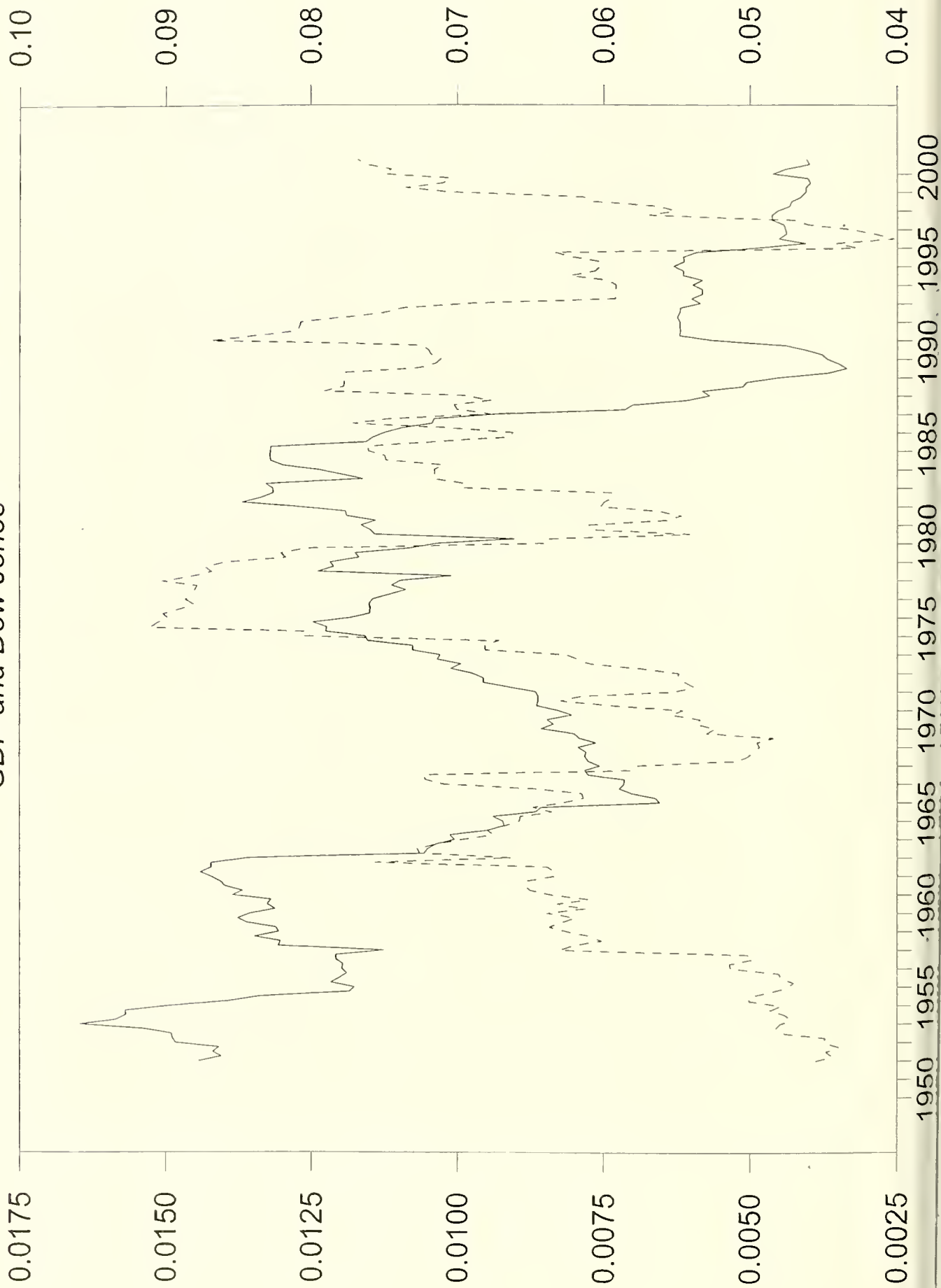
We intend to explore all these avenues in the near future.

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<sup>20</sup>This is not necessarily a puzzle. If we think of the better use of monetary policy as one of the factors behind the decrease in output volatility, stronger stabilization may require larger movements in interest rates, and thus potentially stronger movements in asset prices. There is however little evidence of increased volatility in real interest rates, let alone nominal interest rates.

**Figure 12. Rolling Standard deviations**

*GDP and Dow Jones*





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