Has the Business Cycle Changed? Evidence and Explanations

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Introduction

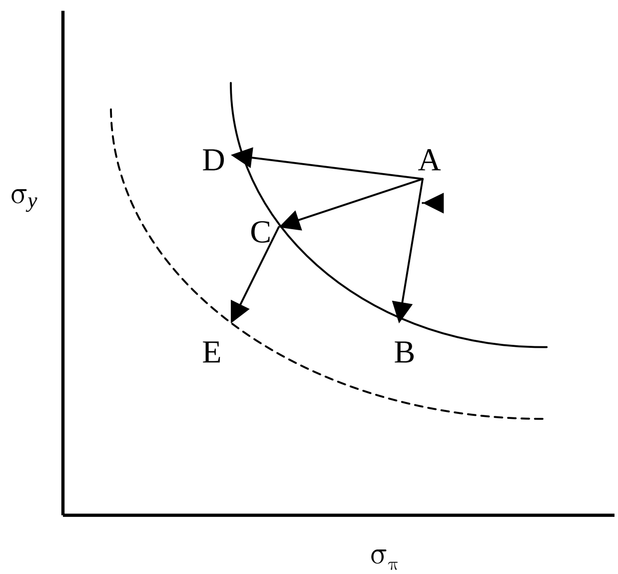
Over the past 30 years, economic activity has become less volatile in most G7 countries. In the US, for example, the standard deviation of the growth rate of GDP, averaged over four quarters, was one-third less during 1984 to 2002 than it was during 1960 to 1983. This decline in volatility is widespread across sectors within the US and is also found in the other G7 economies, although the timing and details differ from one country to the next. Interestingly, despite these changes and increasing international economic integration, output fluctuations have not become more correlated or synchronized across countries.

Much has been written about the possible causes of this "great moderation." In this paper, we review existing evidence and present some new evidence on these causes. Our main focus is on the hypothesis that the great moderation is a happy byproduct of improved monetary policy. For the US (on which the most data are available and the most has been written), monetary policy is generally thought to have been to too accommodative during the 1960s and 1970s (DeLong (1997), Romer and Romer (2002), Sargent (1999)); this changed in 1979, and for the 1980s and 1990s the Fed showed a commitment to maintaining low inflation.

If improved monetary policy tamed inflation, does it not stand to reason that it also produced the great moderation? Not necessarily. The role for monetary policy in the great moderation is summarized in Figure 1, which plots the standard deviation of a measure economic activity against the standard deviation of the rate of inflation. The actual values of these standard deviations depend on the structure of the economy, the shocks experienced by the economy, and the monetary policy followed by the Fed. Different rules produce different values for these standard deviations, and the best that the policymaker can do, given the structure of the economy, is to reach the "frontier" represented by the solid line in Figure 1. The points B, C, and D are achieved by three different policies on the frontier; none dominates the others, in the sense that none has both lower inflation and output volatility than the others. Point A is within the frontier. If A represents the policy of the 1960s and 1970s, inflation volatility could be reduced by moving to any point to its left, for example, to B, C, or D. Whether this shift also reduces

Figure 1

Monetary Policy and the Variability of Output and Inflation



Points B, C, D are on the feasible frontier (solid line) representing the tradeoff between the standard deviation of inflation (σ_π) and the standard deviation of output (σ_y); points B, C, and D all have less inflation volatility than point A, which is within the frontier. Point E is on a frontier that has shifted towards the origin from the original frontier.

output volatility depends on the details of the policy and on the workings of the economy. If the shift is to B, output volatility drops considerably; if it is to C, output volatility falls slightly; but if it is to D, output becomes more volatile. At this level of abstraction, improved monetary policy that reduces inflation variability might also reduce output variability, then again, it might not. This all assumes that the frontier has stayed fixed, but if shocks to the economy are smaller, or if the private sector becomes better at smoothing shocks, then the frontier shifts toward the origin and the policy that led to C would now lead to E: it would appear that the improved policy led to lower output volatility, but most of the volatility reduction is the result of smaller macroeconomic shocks or structural changes in the economy.[1]

The empirical results in this paper suggest that improved monetary policy accounted for only a small fraction of the reduction in the variance of output growth from the pre-84 period to the post-84 period in the US, and that the bulk of the great moderation arose from shifts in the frontier; in terms of Figure 1, we think that the path "A-C-E" provides the most plausible description of the improved macroeconomic performance of the past two decades. This argument requires estimating how the post-84 economy would have evolved, had the monetary policy of the 1970s been in place, and to answer this question we use four different modern econometric models, ranging from a backward-looking vector autoregression to a forward-looking nine-equation dynamic stochastic general equilibrium model. Remarkably, these different models lead to the same conclusion: although improved monetary policy played a key role in getting inflation under control, it played at best a modest role in the great moderation. This conclusion is reinforced by the international evidence.

This leaves an important question: why did the frontier shift in, and is this shift likely to be permanent or temporary? We conclude that part of the inward shift could be permanent, but the empirical evidence suggests that much – half or more – of the great moderation could be temporary, the result of smaller macroeconomic shocks, in particular smaller common international shocks. Were these common international shocks to become again as large as they were in the 1970s, volatility would increase throughout the G7 and the G7 business cycles would become more synchronized.

[1]Taylor (1979) presents a graph like our Figure 1 with the frontier and point A estimated empirically.

Before turning to the evidence, we make a few general comments about the analysis. Although we discuss aspects of changes in the business cycle for all the G7 economies, because of data limitations and space constraints our discussion focuses primarily on the U.S. Our interest is on changes in the business cycle; changes in time series properties at very high frequencies can be the consequence of changes in survey methods or other features not directly germane to business cycle analysis, and structural economic changes that affect long-term growth rates, while certainly important, bear only indirectly on short-term macroeconomic management. We therefore take Hall's (2002) advice and use transformations of the data that focus on fluctuations at business cycle frequencies. For real series, we examine four-quarter growth rates; for GDP, this is $100\ln(GDP_t/GDP_{t-4})$. Longer growth rates, while also of interest, reduce the number of non-overlapping observations. The models and analysis specific to the US uses real GDP, but for cross-country comparisons we use real GDP per capita.

Changes in the Business Cycle in the G7, 1960 - 2002

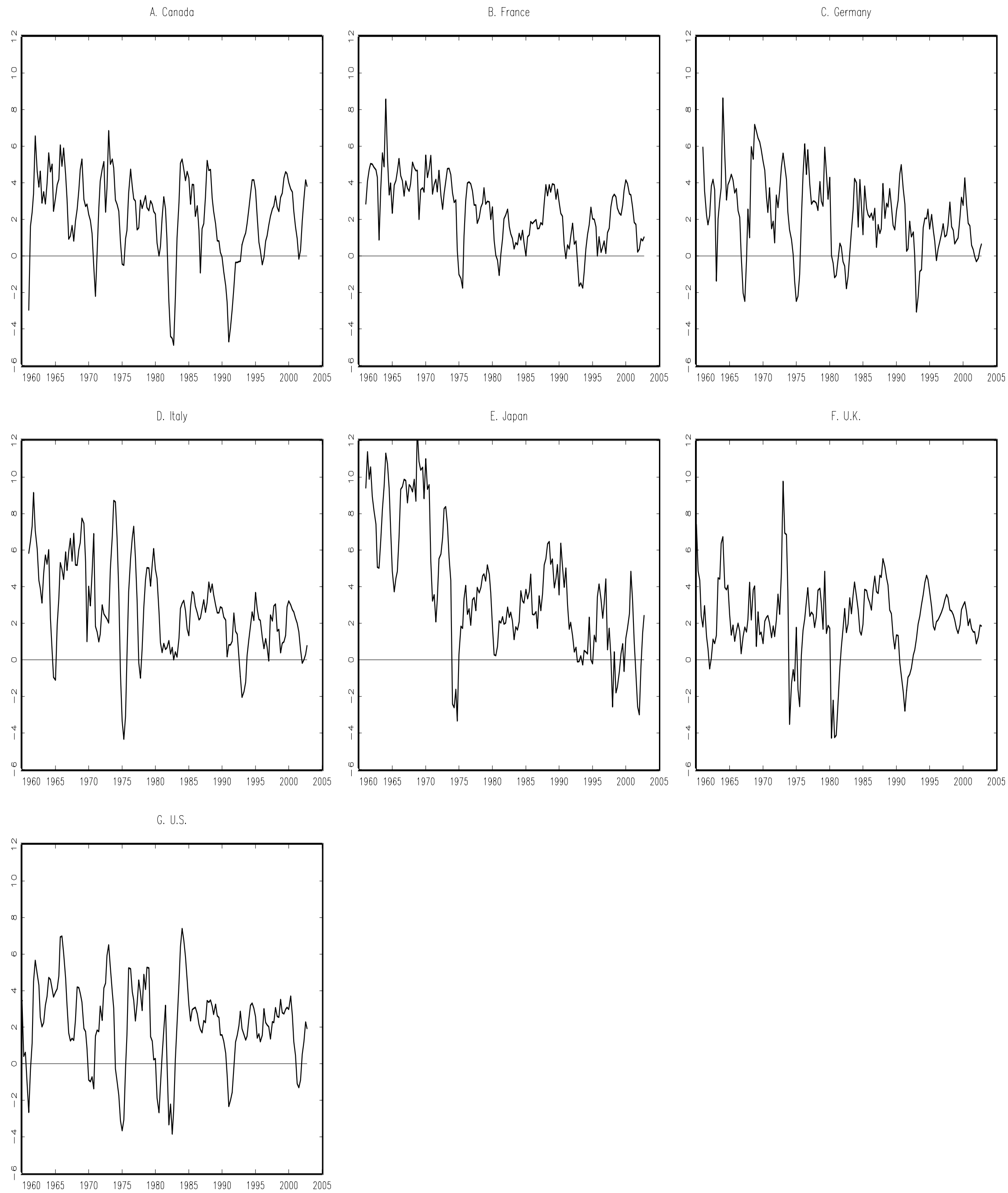
The business cycle has changed in important ways over the past four decades: output fluctuations have moderated, GDP growth is easier to forecast, and shocks to GDP are more persistent. Curiously, one thing that has not changed is the degree of synchronization of business cycles among the G7.

Widespread but Varied Reductions in Output Volatility

Perhaps the most striking change in the business cycle over the past three decades has been the dramatic decline in the volatility of GDP growth in most G7 economies. In the US, this "great moderation," first documented by Kim and Nelson (1999) and McConnell and Perez-Quiros (2000), is well characterized as a sharp reduction in the variance of GDP growth in the mid 1980s; using different econometric techniques and working independently, both Kim and Nelson (1999) and McConnell and Perez-Quiros (2000) estimate a break date of 1984.

Figure 2

Four-quarter growth rates of GDP per capita



This decline in cyclical volatility has occurred not just in the US but, to varying degrees, in the other G7 economies as well. Figure 2 plots the four-quarter growth rate of GDP for the G7 economies over the past four decades. As is summarized in Table 1, the standard deviation of four-quarter GDP for France, Germany, Italy, Japan, the UK, and the US over the period 1984 – 2002 is less than three-fourths what it had been during the earlier period, 1960 – 1983. Indeed, the variance of four-quarter GDP growth in these six countries fell by 50% to 80%.[2]

Table 1
Changes in Volatility of Four-Quarter Growth of Real GDP per Capita in the G7, 1960 – 1983 and 1984 – 2002.

	Standard deviation, 1960 – 1983	Standard deviation, 1984 – 2002	std. dev. 84-02 / std. dev. 60-83	variance 84-02 / variance 60-83
Canada	2.3	2.2	.96	.91
France	1.8	1.4	.71	.51
Germany	2.5	1.5	.60	.36
Italy	3.0	1.3	.43	.19
Japan	3.7	2.2	.59	.35
UK	2.4	1.7	.71	.50
US	2.7	1.7	.63	.40

Notes: Entries in the first two columns are the standard deviations of the four-quarter growth in GDP over the indicated time periods. The third column contains the ratio of standard deviation in the second column to that in the first; the final column presents the square of this ratio, which is the ratio of the variances of four-quarter GDP growth in the two periods. Data sources are given in the Data Appendix

The estimates in Table 1 use the 1984 date of the volatility shift in the US, but this date or the single-break model might not be appropriate for other countries. In addition, the standard deviations in Table 1 might confound changes in the trend growth rate of output in these countries with changes in business cycle fluctuations. In fact, Germany, France, Italy, and Japan grew much more rapidly in the 1960s, when postwar

[2]The literature on the great moderation has grown rapidly. Blanchard and Simon (2001) and Stock and Watson (2002) survey studies using US data. Studies using international data include Dalsgaard, Elmeskov and Park (2002), Del Negro and Otrok (2003), Doyle and Faust (2002a), van Dijk, Osborn, and Sensier (2002), Fritsche and Kouzine (2003), Mills and Wang (2000), Simon (2001), and Stock and Watson (2003).

reconstruction was still under way, than in the past two decades, and the standard deviations reported in Table 1 in principal contain the two effects of changing cyclical fluctuations and decadal changes in the mean growth rate. It is therefore desirable to obtain alternative estimates of the time path of volatility which do not rely on a single break date and are robust to movements in the long-term growth rate of output.

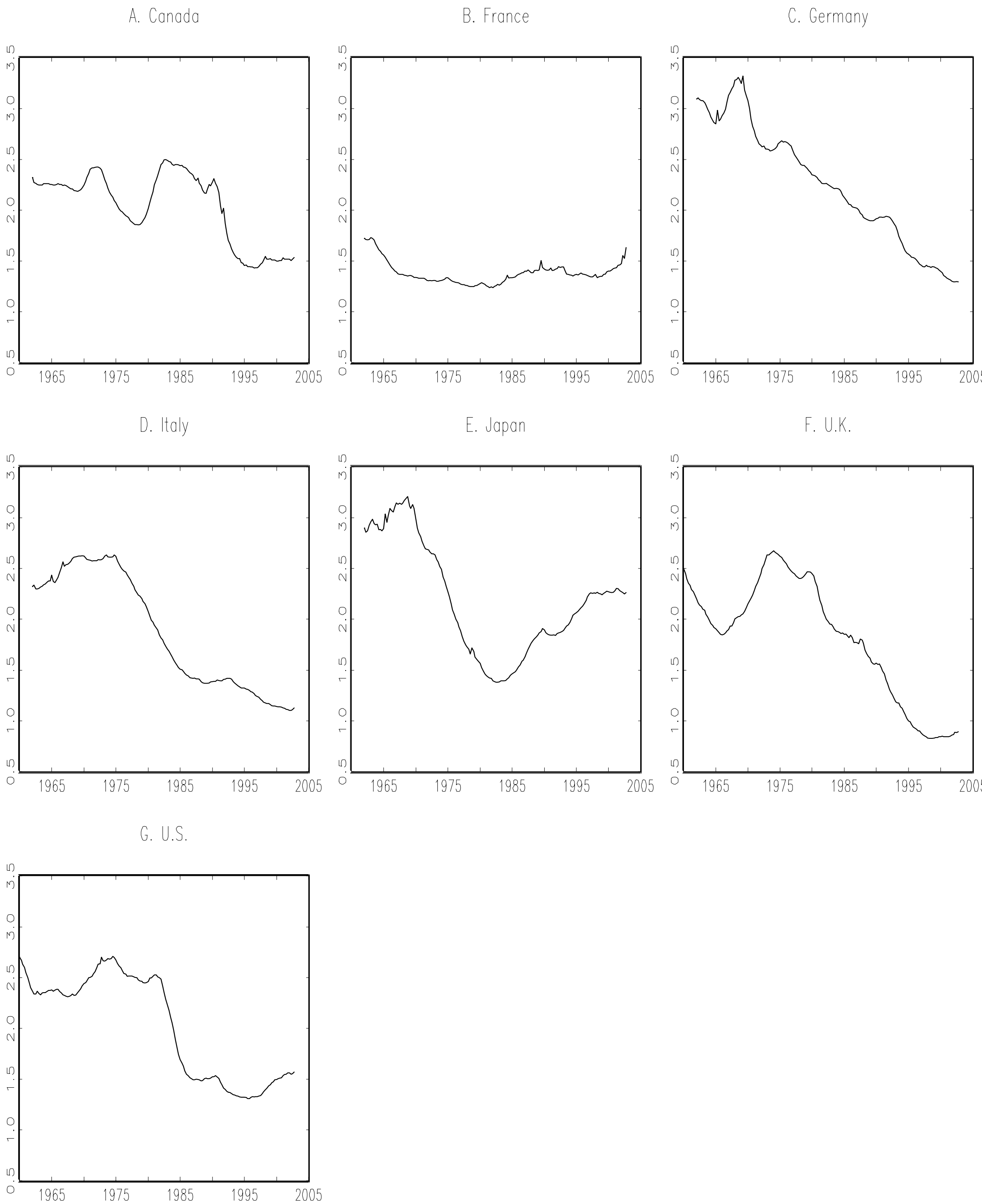
Accordingly, Figure 3 plots estimates of the instantaneous standard deviation of four-quarter GDP growth in these economies. These estimates are based on an autoregressive model with time-varying coefficients that allow for a long-run GDP growth rate that varies over time.[3] These estimated volatility paths show a broadly similar pattern as Table 1, although some details differ. The estimates for Canada in Figure 3 show a large decline in volatility, but this decline occurs in the early 1990s, not the mid-1980s. The estimates for France suggest that there has been little change in volatility over most of the past thirty years. The volatility decline for Germany is very large and, according to the Figure 3 estimates, is nearly a straight-line decrease. The volatility decline in Italy and the UK preceded that in the US, while in Japan volatility is estimated to have fallen in the 1970s but then increased again in the late 1990s. In short, while there is clear statistical evidence of a reduction in volatility in (at least) Germany, Italy, Japan, the UK, and the US, the particulars of magnitude and timing differ substantially from one country to the next.

A related aspect of the great moderation is that, at least in the US, expansions have grown longer and recessions shorter; the 120-month US expansion of the 1990s is the longest in the 140 years covered by the NBER chronology, the 92-monthy expansion of the 1980s is the third-longest, and the two post-84 recessions were both short, only 8 months. These changes have a straightforward interpretation. If the long-term growth rate of output is constant and its variance decreases, then (all else equal) periods of

[3]The estimates in Figure 3 are taken from Stock and Watson (2003). The instantaneous standard deviation is computed by first estimating a stochastic volatility autoregressive model with time varying parameters, specifically, $y_t = \alpha_{0t} + \sum_{j=1}^{p} \alpha_{jt} y_{t-j} + \sigma_t \varepsilon_t$, where $y_t = \Delta \ln GDP_t$, $\alpha_{jt} = \alpha_{jt-1} + c\eta_{jt}$, $\ln \sigma_t^2 = \ln \sigma_{t-1}^2 + \zeta_t$, ε_t, $\eta_{1t}, \ldots, \eta_{pt}$ are i.i.d. $N(0,1)$, and ζ_t is drawn from a mixture-of-normals distribution and is distributed independently of the other shocks. Next, the instantaneous variance of four-quarter GDP growth is computed as a function of the smoothed estimates of the time-varying parameters. For details, see Stock and Watson (2002, Appendix A) and Stock and Watson (2003).

Figure 3

Estimated instantaneous standard deviation of 4-quarter growth of GDP per capita



Source: Stock and Watson (2003).

negative growth become fewer and farther apart. Because recessions are periods of negative growth, a moderation in output volatility with no change in the mean growth rate implies, in this mechanical sense, shorter recessions and longer expansions.[4]

GDP Growth Is More Forecastable and Persistent

The innovations in GDP growth in the G7 have also become smaller in the post-84 period, and in this sense GDP growth has become easier to forecast using simple time series models. Table 2 summarizes some results for simulated forecasts of quarterly GDP growth using univariate time series models. The first pair of columns reports the standard error of the regression for autoregressions with four lags; this one-quarter ahead standard error fell in all seven countries, in several cases by more than one-third. These autoregressions could not have been used for forecasting because they were estimated using data beyond the forecast period. A better way to simulate real-time forecasting is to estimate a different autoregression at each date, where the estimates are based on a moving window of data that would have been available at the date the forecast is made. The root mean squared error of the resulting pseudo out-of-sample forecasts produced this using an eight-year window is summarized in the third and fourth column. The forecast root mean squared errors are somewhat larger than the standard error of the regressions in the first two columns over the post-84 sample in part because the autoregressions in the third and fourth columns were estimated using fewer observations. As in the first two columns, however, the root mean squared forecast errors are substantially less post-84 than pre-84.[5]

[4]This reasoning assumes the long term growth rate to be approximately constant. This is not a good assumption for Germany, Italy, and Japan, where the long-term mean growth rate fell substantially. In the presence of a constant variance, this fall would increase recession lengths and decrease expansion lengths. Accordingly the implications of the great moderation for business cycle phase lengths for those countries require model-based calculations such as those in Harding and Pagan (2002). See Blanchard and Simon (2001) for additional discussion.

[5] Repeating this exercise for forecasts of four-quarter GDP growth shows a similar reduction in pseudo out-of-sample forecast root mean squared errors. These calculations are based on the fully revised data, which were not available to real-time forecasts, so a real-time forecaster might not have realized the forecast improvements apparent in Table 2.

Table 2
Autoregressive Models of Quarterly GDP Growth:
Measures of Forecast Errors and Sum of Autoregressive Coefficients

Estimated Autoregression: $\Delta y_t = \alpha_1 \Delta y_{t-1} + \ldots + \alpha_4 \Delta y_{t-4} + \varepsilon_t$

	Standard error of the regression ($\hat{\sigma}_\varepsilon$)		Pseudo one-step ahead forecast root mean squared error		Sum of α coefficients	
	60-83	**84-02**	**69-83**	**84-02**	**60-83**	**84-02**
Canada	3.82	2.27	4.09	2.78	0.00	0.56
France	2.95	1.79	2.73	2.12	-0.36	0.43
Germany	5.42	3.39	4.89	3.97	0.04	-0.18
Italy	4.03	2.16	5.16	2.47	0.02	0.13
Japan	4.08	3.79	4.65	4.31	0.38	0.09
UK	4.81	1.84	6.40	2.41	0.03	0.65
US	3.98	1.96	4.92	2.27	0.30	0.47

Notes: Estimates in the first two and final two columns were computed using quarterly detrended GDP growth, where the trend growth is modeled as an unobserved random walk with a small innovation variance; for details, see Stock and Watson (2003). The pseudo out-of-sample forecast errors reported in the third and fourth column were computed by estimating a new autoregression for each forecast date using quarterly GDP growth (not detrended) and a moving window of eight years of data which ends one quarter before the quarter being forecasted; the entry is the square root of the average squared forecast error over the indicated periods.

Table 2 also reports a measure of the change in the persistence of a shock to GDP growth, specifically, the sum of the autoregressive coefficients; the inverse of one minus this sum is the cumulative effect of a GDP forecast error on the long-term forecast of GDP, so an increase in this sum implies an increase in the persistence of a univariate innovation in GDP. In Canada, France, the UK, and, to a lesser extent, Italy and the US, the sum of the autoregressive coefficients increased from the first period to the second.

Sectoral Volatility has Decreased

Is the reduction in volatility evident in GDP growth widespread throughout the US economy, or is it limited to certain sectors or series? This question is addressed in Table 3 for 22 major US series consisting of the main NIPA aggregates and selected other macroeconomic time series. As can be seen in Table 3, the volatility of 21 of these 22 series fell in the post-84 period. This said, the decline in the standard deviation is not uniform across series. The standard deviation of nondurables consumption fell by more than it did for services or durables consumption. Similarly, the volatility of nondurable goods production fell by more than the volatility of the production of durable goods or services. Among the measures of real activity, the largest relative decline in volatility occurred in the cyclically sensitive housing sector, in which the post-84 standard deviation is approximately one-half its pre-84 value. Even though the share of residential investment is fairly small, because its variance is so large the reduction in volatility "explains," in an accounting sense, a substantial fraction of the variance reduction in GDP growth; we shall return to this fact below. The volatility of inflation also fell sharply, as did, to a lesser extent, the volatility of short term interest rates. Interestingly, however, the volatility of long-term interest rates increased in this period, another fact to which we return below.

The final two columns of Table 3 report a measure of the comovement of the series with the business cycle, specifically, the correlation between the row series and the four-quarter growth rate of GDP. In the face of the widespread reductions in volatility, the striking result of the final two columns is that this cyclical correlation is virtually unchanged for all the real series.

Table 3
Changes in Volatility and Cyclical Correlations of Major Economic Variables

Series	Standard deviation 1960 – 2002	Ratio of standard deviations, 84-02 to 60-83	Correlation with 4-quarter GDP growth	
			60-83	84-02
GDP	2.30	0.61	1.00	1.00
consumption	1.84	0.60	0.85	0.87
durables	6.55	0.70	0.76	0.80
nondurables	1.65	0.62	0.76	0.77
services	1.17	0.69	0.68	0.71
investment (total)	10.41	0.79	0.88	0.89
fixed investment – total	6.78	0.79	0.85	0.86
nonresidential	6.85	0.93	0.75	0.76
residential	13.25	0.51	0.58	0.57
Δinventory investment/GDP	0.86	0.83	0.64	0.66
exports	6.71	0.72	0.30	0.27
imports	7.25	0.74	0.71	0.68
government spending	2.46	0.71	0.21	0.25
Production				
goods (total)	3.65	0.72	0.95	0.95
nondurable goods	6.98	0.68	0.87	0.89
durable goods	2.10	0.72	0.64	0.66
services	1.08	0.74	0.54	0.58
structures	6.20	0.67	0.80	0.80
nonagricultural employment	1.79	0.71	0.78	0.77
price inflation (GDP deflator)	0.39	0.53	0.16	0.15
90-day T-bill rate	1.73	0.75	0.43	0.39
10-year T-bond rate	1.21	1.10	0.13	0.02

Notes: NIPA series are expressed in four-quarter growth rates (percent at an annual rate), except for the change in inventory investment, which is the annual difference of the quarterly change in inventories as a fraction of GDP. Inflation is the four-quarter change in the annual percentage inflation rate, and interest rates are in four-quarter changes. The first column reports the standard deviation of the row series over the full period, 1960 – 2002. The second column reports the ratio of the standard deviations for the post- and pre-84 subperiods; a ratio less than one means that volatility has moderated. The final two columns report the contemporaneous correlation between the row series and the four-quarter growth rate of GDP.

International Synchronization Has Not Increased

Over the past four decades, world economies have become increasingly linked by trade and financial markets. This increasing interdependence suggests that national business cycles might have become more synchronized. Interestingly, however, this turns out not to have been the case. Table 4 presents contemporaneous correlations between the four-quarter GDP growth rates in the G7 countries in the pre- and post-84 periods. Some of the correlations have increased, such as those between France and Italy and between Canada and the UK, but others have decreased, such as those between the UK and France and between the US and Japan. One general pattern in Table 4 is that the correlations between the Japanese GDP growth and the rest of the G7 have decreased. On average, however, these correlations have remained essentially unchanged: the average cross-country correlation in Table 4 was 0.41 in the first period and 0.36 in the second; excluding Japan, the average was 0.43 in the first period and 0.44 in the second.

Table 4
International Correlations of Four-Quarter GDP Growth Rates

	Canada	France	Germany	Italy	Japan	UK	US
	1960 – 1983						
Canada	1.00						
France	0.31	1.00					
Germany	0.50	0.56	1.00				
Italy	0.30	0.59	0.35	1.00			
Japan	0.20	0.40	0.46	0.28	1.00		
UK	0.26	0.54	0.53	0.13	0.48	1.00	
US	0.77	0.39	0.52	0.21	0.32	0.46	1.00
	1984 – 2002						
Canada	1.00						
France	0.33	1.00					
Germany	0.12	0.59	1.00				
Italy	0.38	0.77	0.59	1.00			
Japan	-0.05	0.28	0.38	0.34	1.00		
UK	0.72	0.33	0.11	0.47	0.09	1.00	
US	0.80	0.26	0.22	0.29	0.02	0.58	1.00

The failure to find an increase in synchronization has stimulated considerable recent research. This general finding is robust to the subsamples used to estimate the correlations, whether the correlations account for lagged effects, and the statistical method used to compute these correlations.[6] It is also consistent with cross-country regressions that try to explain volatility using measures of openness and/or financial integration and, generally, speaking, find no relation or an unstable relation, at least for developed economies (e.g. Easterly, Islam, and Stiglitz (2001) and Buch, Doepke, and Pierdzioch (2003))

Improved Monetary Policy and the Great Moderation

Did improved monetary policy cause the great moderation? We investigate this possibility by first documenting the quantitative evidence on changes in monetary policy and laying out the arguments suggesting that, at least in theory, these changes could have reduced output volatility. To quantify this effect, we enlist three econometric models of the US economy, plus one of the Eurozone, which range from a purely backward-looking VAR to a nine-equation rational expectations system. These models all estimate the contribution of improved monetary policy to the volatility slowdown to be small.

Quantitative Evidence of Changes in Monetary Policy.

The past thirty years have seen great changes in the institutions and practice of monetary policy. At the Federal Reserve, the monetary policy of the 1960s and 1970s, now widely seen as having permitted the great inflation of the late 1970s, was replaced by a commitment to low inflation made credible by the twin recessions of 1979 – 1982. At the Bank of England, years of political management of monetary policy gradually yielded to increasing independence, an explicit inflation target, and, eventually formal independence from the Treasury. In continental Europe, political agreement on the Maastricht criterion for inflation led to sweeping changes in monetary policy,

[6] See Dalsgaard, Elmeskov and Park (2002), Doyle and Faust (2002a, 2002b), Heathcoate and Perri (2002), Kose, Prasad, and Terrones (2003), Monfort, Renne, and Vitale (2002), and Stock and Watson (2003)). Some researchers have suggested the emergence of a Euro-zone business cycle (Artis, Kontelemis, and Osborn (1997), Artis and Zhang (1997, 1999), Carvalho and Harvey (2002), Helbling and Bayoumi (2003), Dalsgaard, Elmeskov and Park (2002), Del Negro and Otrok (2003), Luginbuhl and Koopman (2003)); however the time period available to assess this possibility is short so it is difficult to draw clear statistical conclusions and we do not pursue this finding here.

culminating with inflation range targeting by the ECB. Now, throughout the G7, inflation is quiescent and is at or near postwar lows.[7]

One way to see whether these qualitative changes are reflected in quantitative measures of monetary policy is to estimate rules of the form suggested by Taylor (1993) using historical data from different episodes. Taylor-type rules relate changes in the short term interest rate R_t (in the US, the Fed Funds rate) to deviations of inflation from target and the size of the output gap:

$$R_t = r^* + \pi^* + g_\pi(\bar{\pi}_t - \pi^*) + g_y(y_t - y_t^p), \tag{1}$$

where r^* is the long-term equilibrium real interest rate (at an annual rate), $\bar{\pi}_t$ is the rate of inflation averaged over four quarters (also expressed at an annual rate), π^* is the target rate of inflation, y_t is the logarithm of GDP in quarter t, y_t^p is the logarithm of potential GDP (so that $y_t - y_t^p$ is the output gap), and g_π and g_y are coefficients that govern the response of interest rates to deviations of inflation from target and to deviations of output from potential. Taylor (1993) originally suggested the coefficients $g_\pi = 1.5$ and $g_y = 0.5$, so that the central bank responds to a one percentage point increase in the rate of inflation sustained for four quarters by increasing the short rate by 150 basis points.[8]

Table 5 collects estimates of historical Taylor-type rules estimated using US data by Judd and Rudebusch (1998), Taylor (1999), and Clarida, Gali, and Gertler (2000). According to these estimates, before 1979 the key coefficient on inflation, g_π, was less than one; that is, an increase in the rate of inflation was met by a smaller increase in the short rate and thus an effective reduction in the real rate, potentially leading to an unstable spiral in which increases in the rate of inflation led to expansion by the Fed. In

[7] For accounts of these institutional and policy changes in the US, see DeLong (1997), Romer and Romer (2002), Sargent (1999); for an international perspective, see Bernanke and Mishkin (1992) and Bernanke et. al. (1999).

[8] In practice, monetary policy necessarily involves discretion and considers many variables, not just the rate of inflation and the output gap; strictly, none of this is permitted under the Taylor rule (1). Moreover, the Taylor rule is difficult to implement in real time because of the large uncertainty about the level of potential output (e.g. Kohn (1999)). Our immediate purpose is not, however, to dispense policy advice. Rather, it is to quantify the key broad features of monetary policy over the past thirty years, a job for which the Taylor rule provides a useful modeling simplification.

contrast, the post-1979 estimates have inflation coefficients greater than one (and close to Taylor's recommended value of 1.5), indicating a reduction in the real rate in response to an increase in the rate of inflation. In short, these estimates provide a concise quantitative summary of the qualitative history of Fed policy.[9]

Table 5
Estimates of Historical Taylor Rule Coefficients for the US

	Pre-79		1979 – 1987		Post-1987	
Source	g_π	g_y	g_π	g_y	g_π	g_y
Judd and Rudebusch (1998)	0.85 (0.19)	0.88	1.69 (0.52)	0.36	1.57 (.21)	0.98
Taylor (1999)	0.81	0.25			1.53	0.77
Clarida, Gali, Gertler (2000)	0.83 (0.07)	0.27 (0.08)	2.15[a] (0.40)	0.93[a] (0.42)	2.15[a] (0.40)	0.93[a] (0.42)

Notes: Entries are the indicated authors' estimates of the Taylor rule coefficients in (1), estimated using historical data for the US; standard errors are in parentheses. The authors used different specifications to obtain these estimates. Judd and Rudebusch (1998) estimated a dynamic Taylor rule over the periods 1970:1 – 1978:1, 1979:3 – 1987:2, and 1987:3 – 1997:4, with lagged values of the output gap and interest rates, and use the Congressional Budget Office (CBO) model for potential output; their reported results include standard errors for their estimates of g_π but not of g_y. Taylor (1999) estimated (1) over the periods 1960:1 – 1979:4 and 1987:1 – 1997:3 using as an estimate of potential output the Hodrick-Prescott low frequency trend of log GDP; he did not report standard errors adjusted for the serial correlation in the error term. Clarida, Gali, and Gertler's (2000) dynamic Taylor rule replaces inflation and the output gap in (1) with their forecasted value one quarter hence. They estimated the resulting rule by generalized method of moments over the periods 1960:1 – 1979:2 and 1979:3 – 1996:4, using the CBO output gap and the one-quarter (not four-quarter) rate of inflation.
[a]Estimates are based on a combined sample of 1979:3 – 1996:4.

[9]Other studies which find that US monetary policy became more aggressive after 1979 include Boivin and Giannoni (2002) and Cogley and Sargent (2001, 2002). Interestingly, based on an analysis of real-time data, Orphanides (2001, 2002) suggests that this change might not reflect a shift in the preferences of the policymakers, who always intended to respond aggressively to inflation, but rather flaws in their estimates of potential GDP, which failed to detect the productivity slowdown of the early 1970s. Under Orphanides' story, policymakers in the 1970s thought they were being more aggressive than they actually were. The large institutional shifts of the hard ERM period and the transition to monetary union, with their short sample periods, make it difficult to quantify shifts in policy in Europe, although Clarida, Gali, and Gertler (1998) provide some evidence.

In Theory, Improved Monetary Policy Could Account for the Great Moderation

At the risk of oversimplification, the main theoretical arguments that improved monetary policy produced the great moderation can be put into three groups: arguments involving unstable equilibria, indeterminate or multiple equilibria, and anchored inflationary expectations.

Unstable equilibria. As Taylor (1993, 1999) emphasized, if the Taylor rule coefficient on inflation is less than one then the economy can become unstable, in the sense that a surprise increase in the rate of inflation results in insufficient tightening. Technically speaking, in many economic models, especially those with a limited role for rational expectations, an insufficiently aggressive monetary policy can result in an explosive root in the difference equation describing the model's dynamics. This explosive root results in time paths for output and inflation that are unstable, so that inflation can, and eventually will, depart arbitrarily far from its target value, and output can deviate arbitrarily far from potential. Over an infinite horizon, this implies inflation and output gap paths that have an infinite variance. Of course, we would not observe an infinite variance in a finite time period; instead, the infinite variance result should be taken as suggesting that over horizons of interest, for example twenty years of a policy regime (1960 – 1979, for example), the variances of inflation and the output gap could be very large. In contrast, in these models a more responsive policy with an inflation coefficient greater than one and a sufficiently large coefficient on the output gap produces stable roots and stationary paths for inflation and the output gap, suggesting that over the twenty years of a policy regime we would observe smaller variances of inflation and the output gap. Judd and Rudebusch (1998) provide a clear illustration of the link between Taylor rule coefficients and unstable equilibria using a backwards-looking model, the Rudebusch-Svensson (1999) model, one of the models we examine below.

Indeterminate (multiple) equilibria. A more arcane implication of insufficiently aggressive monetary policy is that, at least in some models, there can be multiple equilibria. Rational expectations play a key role in these models, and the multiple equilibria arise because of self-fulfilling expectations: expecting an inflationary boom makes it happen, because individuals in the economy correctly understand that the Fed will respond too passively to an inflationary shock. Prices can jump for reasons unrelated to economic fundamentals, and once they do, the increase gets built into expectations and hence into future inflation: these are models with "sunspot" equilibria. For a simple model with this feature, see Clarida, Gali, and Gertler (2000).

Unlike the problem of explosive roots, in these models the sunspot equilibria are stable; the problem, from the point of economic performance, is that some of the equilibria have large "sunspot" changes in expectations that lead to high variances of inflation and output gaps. If, however, the inflation and output gap policy responses are known to be sufficiently aggressive, then individuals recognize that the central bank will not accommodate an inflation shock, thereby eliminating these high-volatility sunspot equilibria.

Anchored inflationary expectations. A related argument emphasizes the role of credibility of the central bank. Before 1979, the reasoning goes, policymakers had no credible commitment to low inflation; as DeLong (1997) argues, the preconceptions of policymaker, and indeed the institutional relation between the Fed and elected politicians, resulted in a bias toward expansionary policy. Establishing anti-inflation credibility took the recessions of 1979 – 1982 and a clear commitment to low inflation. DeLong (1997), Sargent (1999), and Romer and Romer (2002) tell parts of this story differently, but a common theme is that Fed slowly learned about the dangers of inflation and about the pitfalls of trying to exploit a short-run Phillips curve; having gone through this process, the Fed now commits to lower inflation through implicit inflation targeting. Even without an explicit inflation target, according to this line of reasoning, this credible commitment anchors long-term inflationary expectations. On a technical level, having a credible commitment to control inflation is important for anchoring long-term inflationary expectations (see for example Albanesi, Chari, and Christiano (2003)).

According to this argument, once long-run inflation expectations are anchored, monetary policy is free to be an effective tool for stabilizing output. Macroeconomic shocks today might be as large as they were in the 1970s, but with inflationary expectations pinned down, the Fed can respond to shocks more nimbly and effectively, thereby dampening output fluctuations.

Quantitative Evidence Based on Four Macro Models

To quantify the effect of improved monetary policy on output volatility, one needs to be able to estimate the counterfactual effect of changing a monetary policy rule, holding constant the structure of the economy. Performing this calculation requires an econometric model. We take a catholic perspective and consider four very different models: Rudebusch and Svensson's (1999) three-equation backwards looking model of the US (RS); Stock and Watson's (2002) three-equation structural VAR (SVAR); Smets and Wouters' (2003b) rational expectations dynamic stochastic general equilibrium model of the US (SW-US) with nine endogenous variables, and Smets and Wouters' (2003a) similar nine-equation model of the Eurozone (SW-EU).

The particulars of these calculations are rather involved and are reported in the Technical Appendix to this paper (available at the authors' Web sites). Here, we highlight the most important points. In general terms, each of the four base models applies to the post-84 data, using a post-84 policy rule. The monetary policy rules in these models are versions of Taylor rules but their exact specifications differ. In each case, the post-84 Taylor rule coefficients are nonaccommodative and are broadly similar to the estimates reported for post-1979 rules in Table 6. The models were then solved to estimate the variance of four-quarter GDP growth and the mean and variance of inflation. In all the models, because the monetary rule was sufficiently responsive, equilibria were stable and determinate in the base case.[10]

Next, the post-84 policy rule was replaced with a pre-79 policy rule, while the other model parameters were left unchanged. For the RS model, this resulted in an explosive root. To compare the results of this model to the 1961 – 1979 data, we followed Judd and Rudebusch (1998) and simulated a 19-year sample of data from the model, where the shocks were the actual shocks from 1984 to 2002; this is a model-based simulation of how the US economy would had evolved had the parameters and specific history of shocks been what they were in 1984 – 2002 but policy followed the

[10] The RS and SVAR base models, including their base policy rules, were estimated using post-84 data (we reestimated the RS and SVAR models using the original specifications and data from 1984 – 2002). The SW-US and SW-EU base models were estimated by the original authors using a single full sample, in the US case 1957-2002 and in the EU case 1980-1999; the original SW estimated policy rule coefficients are very close to the Taylor coefficients of 1.5 and 0.5 and thus reflect post-84 policy.

pre-79 rule (which, in the RS model, has an inflation response coefficient of 0.63). (For comparability, the analogous nineteen-year sample variance was used for the RS model in the base case as well.) Because the SVAR specifies a unit root in inflation, the same 19-year simulation approach was used for the SVAR. In the SW-US and SW-EU models, following Clarida, Gali, and Gertler (2000) we selected a pre-79 policy that is accommodative but remains just inside the determinate region. Thus the SW-US and SW-EU models have unique equilibria under our pre-79 policy, even though the inflation response is somewhat less than one (determinacy is a property not just of the rule but of the fully solved model). All this resulted in two estimates of the variance of four-quarter GDP growth for each model: the base case estimate of the post-84 variance, and the counterfactual estimate of what this variance would have been, had the monetary authorities conducted pre-79 policy but all else, including shock magnitudes, was as it was post-84.

The results are summarized in Table 6. For two of the models (RS and SW-EU), the standard deviation of four-quarter output growth increases slightly in the "accommodative monetary policy" counterfactual scenario, while for the other two (SVAR and SW-US), the standard deviation of output falls slightly under the counterfactual scenario. The very small increase in output volatility in the RS model might seem particularly surprising, because the RS model has an explosive root in the counterfactual scenario. Simulation of that model reveals, however, that the explosive root results in unstable behavior at very low frequencies – explosive Kondratieff cycles, in a sense – that eventually result in large deviations of output from potential. At the business cycle frequency that is relevant for the great moderation, however, this explosive behavior simply is not evident over a two-decade time frame.

Table 6
The Effect of Improved Monetary Policy on Output Volatility in Four Econometric Models

	Standard Deviations		Percent of Variance Reduction Explained
	Base Model	Base + Pre-79 Monetary policy	
Rudebusch-Svensson	1.67[a]	1.74[a]	7%
Stock-Watson SVAR	1.67[a]	1.63[a]	–4%
Smets-Wouters/US	2.40	2.33	–10%
Smets-Wouters/EU	1.63	1.88	26%
***Historical values*:**			
period	1984-02	1961-79	
standard deviation	1.67	2.48	

Notes: The base model specifications reflect the actual shocks and monetary policy in the US post-84, and the resulting solved model standard deviations of output growth are reported in the first column. The second column reports the solved model standard deviations with pre-79 monetary policy, computed by replacing the post-84 Taylor rule coefficients in each model with pre-79 coefficients. The final row reports the actual sample standard deviations over the post-84 and pre-79 samples. The final column reports an estimate of the fraction of the actual reduction in the variance of output explained by the model, for example, the first entry in the final column is $(1.74^2–1.67^2)/(2.48^2–1.67^2) = .07$, expressed in percentage terms.
[a]Based on 19-year simulation using 1984 – 2002 estimated shocks.

With these results in hand, we can estimate the fraction of the change in variance that is explained by improved monetary policy in each model; the results are reported in the final column of Table 6. The SW/EU model estimates that 26% of the reduction in variance pre-84 to post-84 is a result of improved monetary policy; the RS model estimates this fraction to be 7%; and the SVAR and SW-US estimate it to be slightly negative, so that, all else equal, the more responsive post-84 policy is estimated to have *increased* output volatility slightly. Among the models fit to US data, the largest estimated fraction of the change in variance due to monetary policy is 7%.

The model calculations also produced means and variances of inflation under the counterfactual scenario using pre-79 policy. In each model, the policy regime switch is estimated to have had a large effect on inflation: had the pre-79 policy been in place, the same shocks would have produced high levels and/or variances of the rate of inflation, so that in each model the mean squared error of inflation minus, say, a target of 2.5%, would have been much greater than was actually observed in the post-84 period. In the RS and SVAR models, the level of inflation does not come down under the counterfactual scenario and exceeds 7% at the end of the sample in both models. In the SW-EU model, the variance of inflation increases substantially (by a factor of four) under the counterfactual scenario. (The inflation target in SW/US follows a random walk, making it difficult to compare with the other models.) The details are summarized in the Technical Appendix.

In summary, this diverse collection of models all suggest that improved monetary policy brought inflation under control, but accounts for only a fraction – among the models fit to US data , less than 10% – of the reduction in output volatility.

Revisiting the Arguments that Improved Monetary Policy is the Cause of the Great Moderation

Unstable equilibria. Insufficiently responsive policy rules produce explosive roots, but the calculations in Table 7 suggest that the unstable equilibria are reflected in volatility at longer horizons than the business cycle frequencies of interest here. This is not to say that overly accommodative monetary policy is acceptable or desirable, it is simply to say that, over a twenty-year period, a more responsive policy does not produce a substantial moderation in the cyclical volatility of output growth.

A variant of the "unstable equilibrium" story is that inflation was countered by stop-go monetary policies, in which periods of inaction and creeping inflation triggered a sharp recession induced by monetary policy. Because the policy rules in our four econometric models are linear, strictly speaking the simulations do not address the stop-go hypothesis. Two pieces of empirical evidence, however, cast doubt on this stop-go view. First, the moderation in GDP growth is evident even if recessions are excluded from the pre-79 data. The standard deviation of US four-quarter GDP growth from 1960:1 to 1978:4 is 2.49; excluding 1973:1 – 1975:4 (a period that contained the sixteen-month 1973-75 recession), this standard deviation was 2.05; but during the 1984 – 2002 period, this standard deviation was 1.67. Evidently the pre-79 volatility was present not just in the "stop" periods but in the "go" periods as well. More to the point, the simulations in Table 7 need the linear Taylor rule to be an adequate approximation to historical policy; ought it instead contain nonlinear terms, such as a threshold once inflation reaches a certain level? To find out, we estimated a variety of nonlinear extensions of dynamic Taylor rules but found scant evidence of nonlinearities, such as threshold effects, that match descriptions of stop-go policies.[11] Even if there were a nonlinear, stop-go policy prior to 1979, as a statistical matter the nonlinear policy seems to be well approximated by the linear Taylor-type rules summarized in Table 7.

Indeterminate (multiple) equilibria. Because the Taylor rule in the SW-US and SW-EU models were chosen to be just within the determinate region, multiple equilibria remain a possibility that is unaddressed in the computations. The question of whether the US economy was in fact in a sunspot equilibrium – an equilibrium in which pricing "mistakes" (more precisely, nonfundamental movements in prices) get built into expectations, which in turn feed into monetary policy – is unresolved in the literature. Today, sunspot equilibria remain a theoretical construct, as once were the ether and the neutrino in physics. We hope that future empirical work will ascertain whether sunspot equilibria do indeed exist (like the neutrino) or whether they do not (like the ether).

In any event, there are reasons to be skeptical that sunspot equilibria can provide a satisfactory resolution of the international evidence on the volatility reduction. Of the G7 central banks, the Bundesbank has the longest history of a credible commitment to inflation reduction, yet the standard deviation of four-quarter growth of German GDP fell by almost half from the pre- to post-84 periods; this change in variance was not sharp, as it might be if the economy emerged from a sunspot equilibrium, but (as is evident in Figure 3) followed a linear trend decline. Similarly, in the UK, the decline in volatility began around 1980, before the decline in the US and well before the drive of the Bank of England towards inflation targeting and institutional independence. France presents a different picture, in which monetary policy underwent many changes, yet despite these changes output volatility is nearly unaffected at business cycle frequencies. Had sunspot equilibria been present under previous French monetary policy, presumably France too would have experienced excessive output variability in an earlier period.

[11] The results are available in the technical appendix.

Anchored inflationary expectations. This argument is not addressed by the model-based computations reported above. In our four models, the Fed's long-term inflation target is taken as known, as is its policy rule, and the Fed is implicitly modeled as being fully credible. Still, two pieces of empirical evidence are relevant.

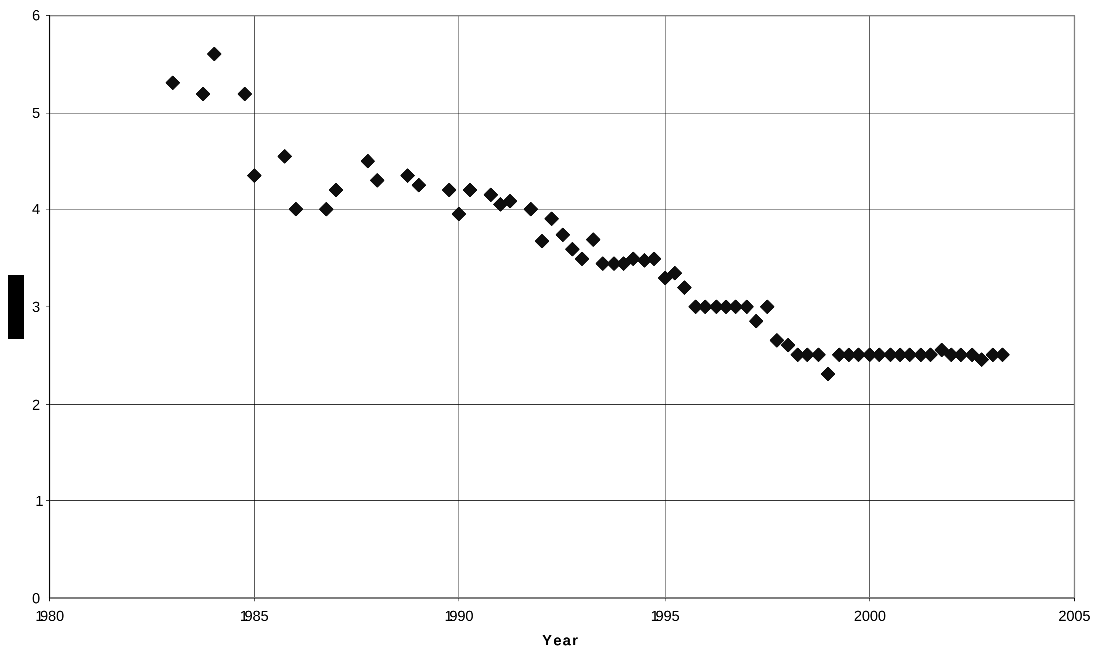
The first piece of evidence concerns the implication of this argument for the short-run tradeoff between inflation and output or, expressed in terms of the unemployment rate, the slope of the short-run Phillips curve. The premise is that anchored inflationary expectations mean that the Fed can affect output growth without affecting inflation. This implies that short-run Phillips curve has become flatter or, more precisely, the sacrifice ratio (the reduction in output required for a given reduction in inflation) has increased. There has been an ongoing debate about whether the short-run Phillips curve has become flatter or, alternatively, whether the NAIRU has simply shifted. Our research on this topic points to the latter (e.g. Staiger, Stock and Watson (2001)), and does not suggest an increase in the sacrifice ratio.

Second, whether inflationary expectations have in fact become anchored is difficult to assess directly, but what evidence there is suggests that if they have, this is a quite recent phenomenon, at least in the US. As is evident in Table 3, the variance of the long-term interest rate increased post-84 even though the variance in the short-term rate fell (also see Watson (1999)). Kozicki and Tinsley (2001) investigated the sources of the variability of long rates from 1980 – 1991 and concluded that the most plausible explanation for this volatility was that this movement reflected movements in long-term expected inflation; this conclusion was also reached by Gürkaynak, Sack, and Swanson (2003). Moreover, survey forecasts of long-term inflation, summarized in Figure 4, indicates that professional forecasts of long-term inflation moved substantially over most of the 1980s and 1990s.[12] Admittedly, inflationary expectations may finally have become anchored in the past three or four years, but with such a short span it is hard to test this empirically. In any event, it appears that over the longer period since the mid-1980s, inflationary expectations have been moving substantially, and the timing of this story thus is at odds with the sharp reduction in volatility in the mid-1980s.

[12] We thank Refet Gürkaynak, Brian Sack, and Eric Swanson for bringing these data to our attention.

Figure 4

Long-Term Inflation Forecasts in the US, 1983 - 2003



Source: Federal Reserve Bank of Philadelphia

Discussion and summary. We conclude this discussion of the effects of the change in monetary policy with two additional remarks. First, our analysis of the effects of the change in monetary policy has focused on the usual mid-term notion of monetary policy, that is, the use of the short-term interest rate as a tool for achieving inflation and/or output stabilization goals over the medium term. But central banks have other responsibilities that arguably belong in a broader definition of monetary policy. For example, an important function of central banks is short-term crisis management, such as providing liquidity or taking other actions in response to rapidly developing financial crisis. It is possible that the reduced volatility of output is in part a result of better crisis management by the monetary authorities. This channel is not addressed by conventional models of monetary policy transmission, including the four used here.

Second, our empirical results do not imply that monetary policy has no effect on output growth, nor do they imply that a poor monetary policy – one that was worse, in some sense, than that of the 1970s – could not have increased the volatility of output post-84. Instead, what our results say is that the particular policy change of interest, from the policy of the 1970s to that post-84, had the major impact of bringing inflation under control but happened not to have a large effect on the cyclical volatility of output.

Permanent Shifts in the Frontier?

One group of explanations for the great moderation is that the structure of the economy has undergone permanent changes. These include the hypothesis that the moderation is a consequence of the increasing share of the services in the economy; the hypothesis that new inventory management methods have smoothed production and thus aggregate output; and the hypothesis that financial innovation and deregulation has relaxed liquidity constraints and allowed consumers and businesses better to smooth shocks to their incomes.

The Sectoral Shifts Hypothesis

While cyclically sensitive sectors such as durable manufacturing once constituted a large share of the G7 economies, those shares have fallen and the share of the cyclically quiescent services sector has risen. As pointed out by Burns (1960) and Moore and Zarnowitz (1986), all else equal, this shift should reduce the cyclical volatility of aggregate production growth.

Whether this is an important contribution to the great moderation depends on the relative variances of the various sectors, the magnitude of the sectoral shifts, and whether the correlations among the sectors have changed. To assess this effect, we performed a simple experiment. Suppose that, during the post-84 period, the sectoral shares in, say, the US economy were the same as had been on average in the pre-84 period, but the growth rates of the various sectors took on their actual post-84 values; what would the variance of US GDP growth have been? If it is close to the actual variance of GDP growth in the pre-84 period, then we can conclude that the sectoral shift was a key cause of the moderation of output volatility in the US. On the other hand, if this counterfactual variance is close to the actual post-84 variance, then we can conclude that the sectoral shift was unimportant, compared with the changes in the sectoral variances themselves.

Table 7 reports the results of this calculation for each of the G7 economies, using comparable annual data.[13] For example, the variance of the annual growth rate of US GDP, estimated using the sectoral data, was 6.00 in the pre-84 period and 3.76 post-84; had the sectoral variances been the same as they were post-84, but the weights were the same as their average values pre-84, then the variance of US GDP in the post-84 period would have been 3.96. This is only slightly greater than the value computed with post-84 weights, 3.76. Said differently, the shift to services reduced the variance of annual GDP growth in the US, but not by much, a finding consistent with Blanchard and Simon (2001) and Stock and Watson (2002). The final two columns in Table 7 provide an estimate of the variance reduction, both in variance units and as a percent of the pre-84

[13] The data are annual growth rates, taken from the Groningen Growth and Development Centre 10-sector data base. The 10 sectors are agriculture, mining, manufacturing, construction, public utilities, retail and wholesale trade, transport and communication, finance and business services, other market services, and government services. The German data are for West Germany only.

variance, arising from the sectoral shifts. For France, Italy, and the US, the estimated contribution of the sectoral shift is quite small, less than 10%. For the UK, the estimated contribution is somewhat larger in variance units, and although it appears very large as a percent of the total change in variance (63%), the absolute change is rather small using the 1984 break date of Table 7 (recall from Figure 3 that most of the decline in UK GDP volatility occurred after 1990). For Italy and Japan, the sectoral shift hypothesis goes in the wrong direction, tending to increase volatility as those economies shifted out of agriculture into manufacturing. Only for Germany does the sectoral shift hypothesis seem to explain a substantial amount of the volatility reduction, 24% of the large decline in the variance of GDP growth from 6.81 to 3.17.

Table 7
The Effect of Sectoral Composition on the Variance of Four-Quarter GDP Growth

	Estimated Variances		Counterfactual Variance	Effect of changing sectoral shares on variance	
Sectoral shares:	60-83	84-96	60-83	In variance units	as % of total fall in variance
Sectoral variances:	60-83	84-96	84-96		
France	3.26	1.86	1.92	-0.12	9%
Germany	6.81	3.17	3.67	-0.85	24%
Italy	6.91	1.64	1.44	0.50	-9%
Japan	14.78	4.71	4.14	1.25	-12%
UK	5.49	4.66	4.81	-0.52	62%
US	6.00	3.76	3.96	-0.19	8%

Notes: Let $\sigma^2(i,j)$ denote the variance of annual GDP growth, computed from the sectoral data (ten sectors) for period *i* with share weights being their average values from period *j*, where *i*, *j* = 1 corresponds to 1960 – 1983, and *i*, *j* = 2 corresponds to 1984 – 1996. The variance $\sigma^2(1,1)$ is estimated using the approximation that the annual growth rate of GDP is approximately the share-weighted average of the annual growth rates of the ten individual sectors, so $\sigma^2(1,j) = \text{var}(\omega_{1,1}\Delta X_{1,t} + \ldots + \omega_{1,10}\Delta X_{10,t})$, where $\omega_{1,10}$ is the average share of sector 10 in the first period, $\Delta X_{10,t}$ is the annual growth rate of sector 10 in year *t*, and the variance is computed over period *j*. The first column reports $\sigma^2(1,1)$, the second column reports $\sigma^2(2,2)$, and the third column reports $\sigma^2(2,1)$. The fourth column reports $\frac{1}{2}\{[\sigma^2(2,2) - \sigma^2(1,1)] - [\sigma^2(2,1) - \sigma^2(1,2)]\}$, which (algebra reveals) is an estimate of the reduction in the variance due to the change in the weights, evaluated at the average of the sectoral covariance matrices in the two periods. The final column is the second column, expressed as a percentage of the total variance reduction, $\sigma^2(2,2) - \sigma^2(1,1)$.

Another difficulty for the sectoral shift hypothesis is that the sectoral changes have evolved gradually over the past four decades, but, aside from Germany's long trend towards moderation, the volatility patterns in the G7 are diverse and complex. This observation, plus the estimates in Table 7, suggestion that, outside of Germany, the sectoral shifts hypothesis cannot explain more than a small fraction of the volatility reduction, and even for Germany, three-fourths of the volatility reduction is not explained by sectoral shifts.

The Inventories Hypothesis

A novel explanation of the great moderation is that improved techniques for inventory management has allowed firms better to use inventories to smooth production in the face of unexpected shifts in sales. This hypothesis, proposed by McConnell and Perez-Quiros (2000) and Kahn, McConnell, and Perez-Quiros (2002), has two key pieces of empirical support. First, at the quarterly level in the US, the volatility of production has declined proportionately more than the volatility of sales, especially in the cyclically sensitive durables manufacturing sector. Second, prior to 1984, changes in durable goods inventories were positively correlated with final sales, so that changes in inventories contributed to fluctuations in production, but after 1984 durable goods inventories became negatively correlated with final sales, thereby stabilizing production.

Several recent studies have taken a close look at the inventory management hypothesis, and it appears that the case for this hypothesis is not as strong as the initial evidence suggested. One set of concerns, based on calibrated theoretical models of inventories, is that improvements in inventory management technology will have at most a modest effect on the volatility of production (Maccini and Pagan (2003)). Moreover, standard inventory models suggest that, even in the absence of a change in inventory management methods, changes in the time series properties of firm-level sales can produce reductions in the volatility of production as large as those seen in the aggregate data (Ramey and Vine (2003)). There is, in fact, evidence that the time series process of sales has changed over the past twenty years at the firm level, becoming *more* rather than less volatile (Comin and Mulani (2003)), an observation consistent with the increased volatility of returns on individual stocks (Campbell et. al. (2001)).

Other concerns relate to the aggregate time series evidence. If inventory management improves because of information technology, such as real-time use of scanner data to track sales, then all else equal the inventory-sales ratios should fall. However, inventory-sales ratios have fallen mainly for work-in-progress and raw materials inventories, not for the final good inventories that are used to smooth production; in fact, inventory-sales ratios have increased for finished goods inventories and for retail and wholesale trade inventories. Moreover, although the variance of production fell relative to the variance of sales at the quarterly level, this is not so at the longer horizons of business cycle interest: the standard deviation of four-quarter growth in both sales and production is 30% to 40% smaller post-84 than pre-84 across all production sectors, durables, nondurables, services, and structures (Stock and Watson (2002)). This suggests that new inventory management methods might smooth production at the horizon of weeks or months, but this smoothing effect disappears at business cycle frequencies.

Finally, it is difficult to square the inventory management hypothesis with the time series evidence in Figure 3. New technology generally diffuses gradually, yet the volatility reduction in the US was sharp. Volatility began to moderate in the UK earlier than in the US, but we know of no evidence that information technology was used for inventory management more aggressively early on in the UK than in the US. And it is hard to see how improvements in inventory management can account both for the slow, consistent volatility moderation in Germany and for the constancy of GDP volatility in France. While improved inventory management methods have been important at the level of individual firms, this evidence, taken together, suggests that it has not been a major factor in the international tendency towards business cycle moderation.

The Financial Market Deregulation Hypothesis

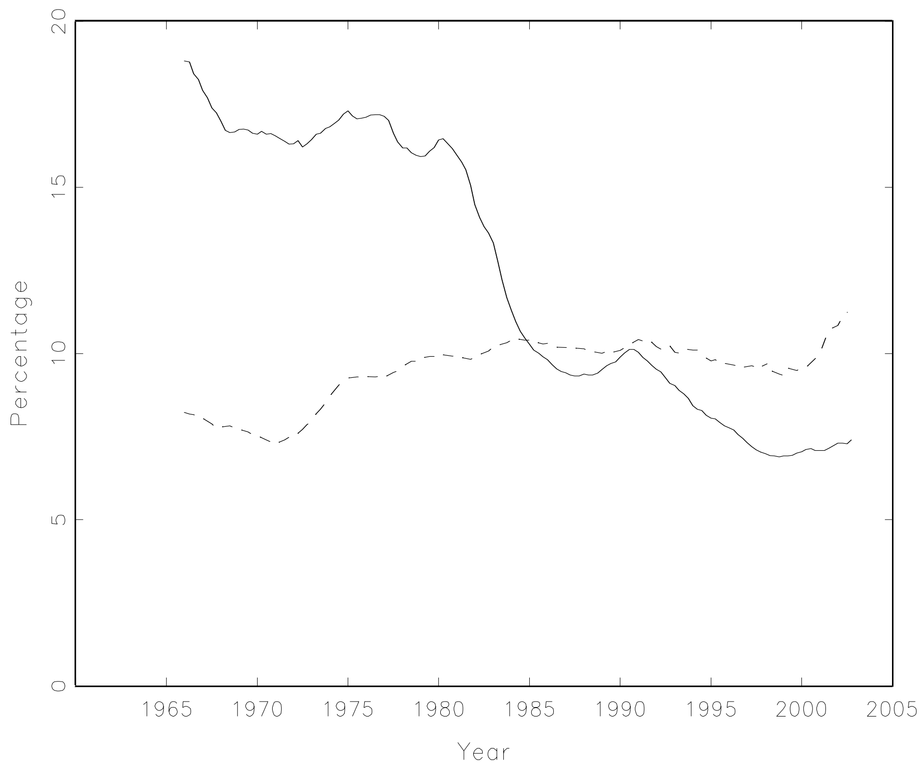
Financial deregulation and new financial technologies have led to major changes in financial markets in the past three decades. For firms, these changes include new ways to hedge risks and improved access to financing. For individuals, these changes include the development of interest-bearing liquid assets, increasingly widespread shareholding, and easier access to credit in the form of credit card debt, mortgages, second mortgages, and mortgage refinancing (see for example McCarthy and Peach (2002)). As Blanchard and Simon (2001) point out, these financial market developments let consumers better smooth shocks to their income, resulting in smoother streams of consumption at the individual level than would have been possible without these reforms. Aggregated to the macro level, this increased access of consumers to credit should result in smaller changes in consumption for a given shock to income and, because consumption accounts for two-thirds of GDP, a moderation of the fluctuations in GDP.

Although the net contribution of this change to the volatility moderation has proven difficult to quantify, some evidence suggest that these changes in financial markets might have played an important role in the great moderation, at least in the US. One sector with large declines in volatility is residential housing. Figure 5 presents estimates of the instantaneous standard deviations of the four-quarter growth of the real value of private residential and nonresidential construction put in place. The residential measure shows a marked declines in volatility during the 1980s and 1990s; in contrast, the volatility of nonresidential construction has been essentially flat over the past three decades. One explanation for the decreased volatility in residential, but not nonresidential, construction is the increased ability of individuals to obtain nonthrift mortgage financing, including adjustable rate mortgages.[14]

[14] Another explanation could be changes in the way these series are collected which induce the changing volatilities observed in Figure 5; see Edge (2000) for a discussion of these data. However, the decline in volatility is evident in other measures of residential construction activity, including building permits, housing starts, and purchases of residential structures.

Figure 5

Estimated instantaneous standard deviation of 4-quarter growth of residential (solid line) and nonresidential (dashed line) construction



Other evidence, however, raises questions about the "financial market changes" hypothesis. Loosening of liquidity constraints should, all else equal, result in smoother consumption paths at the individual level. It appears, however, that over the past twenty years individual-level consumption has become more rather than less volatile (Blundell, Pistaferri, and Preston (2003)).[15] This increased micro-level volatility of consumption might reflect the practical difficulty of using financial markets to smooth consumption, or it might simply be a consequence of greater volatility of individual income streams (see for example Moffitt and Gottschalk (2002)); in any event, additional explaining is needed for this increase in micro-level consumption volatility to be consistent with the implications of the financial market changes hypothesis. A second challenge for the financial market changes hypothesis is that the timing of these changes, which have been ongoing and gradual over the past three decades in the US, does not match the sharp decline in US volatility in the mid-1980s evident in Figure 3. In short, although reductions in the volatility of housing construction suggest that mortgage market developments could have played a significant role in the great moderation, the problems of timing and the increased volatility of individual-level consumption suggest that there is more to the story of the great moderation than financial market developments.

[15] The only panel data set on individual-level consumption is the Panel Survey on Income Dynamics (PSID), which only records food consumption. Blundell et. al. (2003) make their inferences about overall consumption volatility by using econometric models of consumption to combine data from the PSID and from the Consumer Expenditure Survey, a sequence of detailed cross-sectional surveys of consumption. Blundell and Preston (1998) report evidence for the UK of an increase in the variance of micro-level consumption.

Temporary Shifts in the Frontier?

Perhaps the international economy just experienced two decades of good luck in the form of smaller macroeconomic shocks. If so, then the current favorable tradeoff between output variability and inflation variability could worsen if macroeconomic shocks as large as those of the 1970s were to return.

Estimates of the Contribution of Smaller Shocks to the Great Moderation

One way to see whether smaller shocks can account for the reduction in output volatility is to estimate what the standard deviation of output growth would have been under a counterfactual scenario in which monetary policy and economic structure is what is was post-84, but the economy was subjected to shocks as large as those of pre-79. To estimate output volatility under this "big shock" counterfactual, we use two of the four models that we used earlier to compute the "accommodative monetary policy" counterfactuals in Table 6, the RS and SVAR models.[16]

The results are summarized in Table 8, which has the same format as Table 6. Under the counterfactual "big shock" scenario, in both the FS and SVAR models the standard deviation of four-quarter growth would have been much larger than its actual value post-84, and approximately as large as pre-79. Said differently, in the RS model, the decreased shock volatility more than explains the variance reduction from pre-79 to post-84, and in the SVAR the decreased shock volatility explains nearly all of the variance reduction. The variance reductions in the final columns of Table 6 and 8 are not additive for a given model because these variances are not additive functions of the shocks and the monetary policy rules. Still, it is possible to conclude from Tables 6 and 8 that in the RS and SVAR models the output volatility increase arising from using pre-79 shocks is much larger than the increase from using pre-79 monetary policy.

[16] Smets and Wouters (2003a, 2003b) estimated their models over a single sample period, so for SW-US and SW-EU we do not have estimates of pre-79 shock variances in those models. In addition, it is not clear how sensible it is to calibrate the SW-EU model to first-period US shocks (how would Europe have responded to US shocks?).

Table 8
The Effect of Smaller Shocks on Output Volatility in Two Econometric Models

	Standard Deviations		Percent of variance reduction explained
	Base Model	Base + pre-79 shocks	
Rudebusch-Svensson	1.67	2.75	140%
Stock-Watson SVAR	1.67	2.36	82%
***Historical values*:**			
period	1984-02	1961-79	
standard deviation	1.67	2.48	

Notes: The base model specifications reflect the actual shocks and monetary policy in the post-84 US, and the resulting solved model standard deviation of output growth is reported in the first column. The second column reports the solved model standard deviation when actual shocks from 1960-1978 are substituted into the model. The final row reports the actual sample standard deviations over the post-84 and pre-79 samples. The final column reports an estimate of the fraction of the actual reduction in the variance of output explained by the replacement of 1984-2002 shocks with 1960-1978 shocks, for example, the first entry in the final column is $(2.75^2–1.67^2)/(2.48^2–1.67^2)$, expressed in percentage terms.

The estimates in Table 8 are consistent with others in the literature on the great moderation. As discussed above, there has been an improvement in predictability, that is, a reduction in the one-step ahead forecast error variance which is approximately as large as the reduction in the variance of the series itself. In a univariate time series model, the variance of the series scales in direct proportion to the variance of the one-step ahead forecast error, so in this sense essentially all of the reduction in the variance of four-quarter GDP growth is accounted for by a reduction in the forecast error variance. Other studies reaching this conclusion, using either univariate time series methods or reduced-form vector autoregressions, include Ahmed, Levin and Wilson (2001), Blanchard and Simon (2001), Sensier and van Dijk et. al. (2001), and Stock and Watson (2002). In addition, the proposition that the volatility reduction is the result of missing shocks is consistent with the sectoral evidence in Table 3, which shows an absence of change in business cycle correlations and the widespread volatility reductions across sectors and other real activity measures. The pattern in Table 3 is what one would expect to see if little changed on the real side of the economy, except that the standard deviations of all economic shocks fell by one-third.

What Are the Missing Shocks?

The claim that shocks were smaller post-84 than in the 70s begs for some speculation about what the missing shocks were. One candidate is oil shocks, more specifically, fewer oil supply disruptions. Another is smaller productivity shocks, that is, unexpected (and, possibly, unrecognized) movements in productivity.

Oil shocks. Work by Hooker (1996) and Hamilton (1996, 2003) indicates that oil price fluctuations have had less impact on the US economy in the 1980s and 1990s than they did in the 1970s. One possibility is that individuals and firms have adapted to oil price fluctuations. Hamilton (2003) provides a more nuanced interpretation, in which the oil price fluctuations that matter for macroeconomic stability are those that are associated with political upheaval and major supply disruptions, which in turn increase uncertainty in the minds of consumers and investors and, in some cases, induce rationing of petroleum products. Because all but one of the disruptions Hamilton (2003) identifies as important and exogenous occur before 1984, this interpretation also explains the recently small measured effect of oil prices on the economy. Both these views – oil price effects having simply disappeared, and oil price effects being only associated with supply disruptions – explain the historical data, but they have different implications in the sense that one of them leaves the door open for oil shocks, in the form of oil supply disruptions and turmoil in the Mid-East, being potentially important in the future.

Productivity shocks. Both the pre- and post-84 periods contained large, persistent changes in the trend growth rate of productivity. There are, however, reasons to think that these events, as well as the smaller productivity shocks that occurred, were smaller in the latter period than in the former.

There is no single universally accepted series of productivity shocks. One method of measuring productivity shocks, proposed by Gali (1999), is to identify productivity shocks in a structural VAR as the shocks that lead to permanent changes in labor productivity; identified thus, the standard deviation of Gali's productivity shock series falls by 25% post-84, relative to pre-84.[17] Moving away from model-based estimates, the most important productivity events in the two periods were not shocks to the level of productivity, but persistent changes in its growth rate: the productivity slowdown of the early 1970s, and its resurgence in the mid 1990s. Aside from the obvious difference of sign, however, these two productivity events have other salient features. The productivity slowdown was widespread, in large part associated with a fall in labor and total factor productivity growth in services (Nordhaus (2002)), while its increase in the 1990s has been, to a considerable degree, concentrated in information technology sectors. The 1970s productivity slowdown was slow to be noticed, not just by the Fed (Orphanides (2001)) but by economists more generally; indeed, research on why the productivity slowdown occurred continued well into the 1990s. In contrast, the productivity resurgence was expected by many; the surprise was not that it occurred, but rather that the expected revival, which workers saw all around them, was not evident in measured productivity (recall Solow's famous quip about computers being everywhere except in the productivity statistics). Arguably, an unrecognized fall in productivity leads to less efficient allocations than a recognized increase. In this sense, productivity shocks in the sense of surprise changes, slowly recognized, could well have been larger pre- than post-84.

Changes in International Synchronization

It is initially surprising that, given the integration of the world economy, there has been no increase in synchronization in business cycles among the G7 economies. Why is this, and is it reasonable to extrapolate current international business cycle correlations into the future?

In theory, it is unclear whether increased integration should result in more or less synchronized business cycles. On the one hand, a fall in demand in the US will, all else equal, spill over to its trading partners as a drop in the demand for their exports: demand shocks are exported through trade. Similarly, difficulties in one financial market could

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[17] The extent of the decline in the standard deviation of productivity shocks, and perhaps even whether there was such a decline, depends on the measure of productivity shocks used. Measuring the volatility reduction using other measures of productivity shocks and reconciling the results merits further research.

spill over into foreign financial markets, through liquidity, wealth, or more general contagion effects. On the other hand, to the extent that trade induces specialization, then industry-specific shocks will be concentrated in a few economies and correlation could decrease. In addition, integrated financial markets facilitate international flows of capital to economies that have experience productivity shocks, potentially accentuating the effect of those shocks and decreasing international synchronization.[18]

Given this theoretical ambiguity, empirical evidence is needed. Accordingly, it is useful to distinguish between economic shocks and their transmission. In an international context, shocks can be common to many countries (for example, an oil price shock or, possibly, a broad technology shock), or they can be country-specific shocks which can be transmitted through trade linkages. To make this precise, consider a model with two countries; then this distinction between common and country-specific shocks is summarized in the equation,

$$\Delta y_{1,t} = a_1 \Delta y_{1,t-1} + b_1 \Delta y_{2,t-1} + \varepsilon_{1,t} + c_1 \eta_t, \tag{2}$$

where $\Delta y_{1,t}$ is the quarterly growth of output in country 1, $\varepsilon_{1,t}$ is the country-specific shock for country 1, and η_t is the common world shock. A similar equation would hold for country 2. In this stylized model, a world shock affects output growth in both countries directly, although the magnitude of that effect might differ; country-specific shocks affect their own country directly, but spill over to the other country because of international linkages. In this framework, cross-country correlations depend on the magnitudes of the various shocks and their effect on the economies.

Models like (2) have been estimated recently for G7 data by Monfort et. al. (2002), Helbling and Bayoumi (2003), and Stock and Watson (2003). All three studies extend (2) to include an additional international shock and richer lagged effects, but otherwise differ in important details.[19] Despite these differences, the studies reach

[18] For additional discussion, see Doyle and Faust (2002a) and Heathcoate and Perri (2002).

[19] Systems like (2) contain more shocks than observable variables; with seven countries and one common shock, there are eight shocks. Estimation of these systems require factor model methods. Stock and Watson (2003) estimate a seven equation version of (2) with additional lag restrictions. Monfort, Renne, and Vitale (2002) model the international linkages as arising entirely from current and lagged effects of the

similar conclusions. All find evidence of multiple international shocks, and in most countries these shocks explain a large fraction – in some cases, more than half – of the variance of output growth for individual economies. Moreover, over the past two decades common international shocks are estimated to have increased in importance as a determinant of output fluctuations, and the effect of the common international shocks on output growth have become more persistent. These common international shocks have, however, become smaller in magnitude so, despite their increasing effect, on net the international correlations have remained constant. These findings complement those in the previous section and emphasize the importance of the reduction in the variance of the shocks, in this case, the common international shock.

Should we expect international synchronization to be in the future what it is today? According to these models, that depends on one's view of future magnitudes of output shocks. One way to address this is to imagine that output shocks in the next decade were those of the 1970s, but that the transmission mechanism was that of the 1990s. Under this scenario, Stock and Watson (2003) estimate that the average correlation of output growth in the G7 would rise by .15 from its value of the 1990s. Under this "big shock" scenario, business cycles would be both more volatile and more highly synchronized across the G7.

Conclusions

In our view, the evidence on the great moderation suggests that the story summarized by the points A, C, and E in Figure 1 is the most plausible. In 1979, US monetary policy shifted from an overly accommodative policy to one that was sufficiently responsive to inflation, resulting (in Sargent's (1999) phrase) in the conquest of inflation. According to the econometric models we examined, however, this improved monetary policy can take credit for only a small fraction of the great moderation. Instead, most of the reduction in the variance of output at business cycle frequencies

common international shocks, while Helbling and Bayoumi (2003) make a similar assumption, but estimate the system using nonparametric methods.

seems to be the result of a favorable inward shift of the frontier relating the output volatility and inflation volatility.

Whether this inward shift is permanent or transitory is, of course, difficult to know. Some of the shift might be permanent, a result of improved ability of individuals and firms to smooth shocks because of innovation and deregulation in financial markets. There is, however, ample reason to suspect that much of the shift is the result of a period of unusually quiescent macroeconomic shocks, such as the absence of major supply disruptions. Under this more cautious view, a reemergence of shocks as large as those of the 1970s could lead to a substantial increase in cyclical volatility and to a reversal of the favorable shift in the frontier that we have enjoyed for the past twenty years.

Data Appendix

Real GDP series were used for each of the G7 countries for the sample period 1960:1–2002:4. In the cases of Canada, France and Italy, series from two sources were spliced. The table below gives the data sources and sample periods for each data series used. Abbreviations used the source column are (DS) DataStream, (DRI) Global Insights (formerly Data Resources) and (E) for the OECD Analytic Data Base series from Dalsgaard, Elmeskov, and Park (2002), generously provided to us by Jorgen Elmeskov via Brian Doyle and Jon Faust.

Country	Series Name	Source	Sample period
Canada	cnona017g	OECD (DS)	1960:1 1960:4
	cngdp…d	STATISTICS CANADA (DS)	1961:1 2002:4
France	frona017g	OECD (DS)	1960:1 1977:4
	frgdp…d	I.N.S.E.E. (DS)	1978:1 2002:4
Germany	bdgdp,,,d	DEUTSCHE BUNDESBANK (DS)	1960:1 2002:4
Italy		OECD (E)	1960:1 1969:4
	itgdp…d	ISTITUTO NAZIONALE DI STATISTICA (DS)	1970:1 2002:4
Japan	jpona017g	OECD (DS)	1960:1 2002:4
UK	ukgdp…d	OFFICE FOR NATIONAL STATISTICS (DS)	1960:1 2002:4
US	gdpq	Dept. of Commerce (GI)	1960:1 2002:4

The US sectoral, NIPA, and other series used for Table 3 and Figure 5 were obtained from the Global Insight Basic Economics Database. The long-term inflation forecast data plotted in Figure 4 are the “combined” series from the Survey of Professional Forecasters Web site maintained by the Federal Reserve Bank of Philadelphia (http://www.phil.frb.org/econ/spf/). The international sectoral output data used to calculate Table 7 were obtained from the Groningen Growth and Development Centre 10-sector data base.

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