WILL STABILITY LAST?

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Abstract

There is no consensus about the causes of the reduction in business cycle volatility seen in many major economies over the last decade. Using stylised models of the economies of the US, Euro area, UK and Japan, we argue that economic stability has been fostered by improved monetary policy and by associated changes in the behaviour of inflation, which has itself led to a reduction in the volatility of economic shocks. Assuming an absence of cataclysmic events, our projections suggest that most major economies should continue to enjoy an unusual degree of stability.

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Introduction and summary

In Britain, it has been referred to as the "nice" decade – ten years of **n**on-**i**nflationary **c**onsistent **e**xpansion. Americans speak instead of the "Great Moderation". But whatever the designation, the phenomenon is much the same. Over the last decade, the Anglo-Saxon economies have enjoyed a period of unrivalled stability. Activity has continued to fluctuate but less violently, severe recessions have been avoided and inflation has stayed low and stable. The same is true of many other major economies, although Japan and Germany have performed relatively badly.

A burgeoning academic literature, mainly focused on the US experience, has reached a broad consensus about these basic facts[1]. But there is much less agreement about the causes of improved macroeconomic stability (especially the improved stability of output) and whether it will endure.

Some believe that economies have become naturally more self-stabilising as a result of the shift in activity from manufacturing to services or because of better inventory management or the deregulation and integration of financial markets[2]. Others claim that stability stems from better policy making, notably the shift towards central-bank independence and the more effective use of interest rates to contain inflation[3]. A few think that fiscal policy might have contributed[4]. Still others argue that the reduction in the volatility of output, though not of inflation, is largely the result of good luck[5].

Contrasting views about the causes of stability carry over into contrasting beliefs about its likely durability. In keeping with their "good luck" interpretation of the reduction in US output volatility, Stock and Watson (2002) draw "the unsettling conclusion that the quiescence of the past fifteen years could well be a hiatus before a return to more turbulent economic times". Bernanke (2004), by contrast, professes himself "optimistic for the future", in the belief that monetary policy should continue to act in a stabilising fashion. In the UK, the Governor of the Bank of England (King (2003)) occupies a middle ground arguing: "it is almost inevitable that there will be somewhat greater volatility of both output and inflation than the remarkable stability to which we have become used in recent years."

Our paper has four sections. The first summaries key facts about the volatility of business cycles in the major economies and globally. Some of the explanations for their recent tranquillity are briefly reviewed in the second section. We focus in particular on the role that may have been played by the changing behaviour of inflation, a topic only lightly covered by Stock and Watson (2002, 2003b) in their otherwise magisterial surveys. In the next section, we perform counterfactual experiments to reveal the importance of the underlying causes of greater stability. We extend the typical coverage of previous studies that use small macroeconomic models by considering four economic regions – the US, the Euro area, the UK and Japan – and develop a new and comprehensive method of accounting for the change in volatility. We also shed some light on the forces behind the changing volatility of shocks.

In the final section, we project the future volatility of economic growth and inflation in the four regions and their "global" aggregation under various assumptions about the volatility of shocks, the conduct of policy and the long-run steady state of each region. We assess prospects against three criteria: the volatility of growth and inflation, the risk of severe recession and the probability of experiencing zero nominal short-term interest rates. To our knowledge, this has not been done before.

We reach these conclusions:

- Since the Great Inflation of the 1970s, economic stability has been fostered by improved monetary policy and by associated changes in the behaviour of inflation, which has become less self-feeding

[1] On the US, see, for example, Ahmed, Levin and Wilson (2004); Blanchard and Simon (2001); Chauvet and Potter (2001); Kahn, McConnell and Perez-Quiros (2002); Kim and Nelson (1999); Kim, Nelson and Piger (2003); Koop and Potter (2000); McConnell, Mosser and Perez-Quiros (1999); McConnell and Perez-Quiros (2000); Stock and Watson (2002, 2003b); Warnock and Warnock (2000). The changing volatility of non-U.S. activity is examined in Dalsgaard, Elmeskov and Park (2002); Mills and Wang (2000); Smith and Summers (2002); van Dijk, Osborn and Sensier (2002). Buch, Döpke and Pierdzioch (2002b); Debs (2001) and Simon (2001) examine the causes of changing volatility in, respectively, Germany, Canada and Australia.

[2] See, for example, Dalsgaard, Elmeskov and Park (2002); Kose, Prasad and Terrones (2003); McConnell and Perez-Quiros (2000).

[3] See, for example, Bernanke (2004); King (2002); Taylor (1998).

[4] Contrast, for example, Auerbach (2002) with the upbeat assessment of HM Treasury (2004).

[5] See, for example, Ahmed, Levin and Wilson (2004) and Stock and Watson (2002, 2003b).

and less responsive to output. Economic shocks have become less volatile for the same reason; the scale of "shocks" revealed by econometric methods thus depends on the nature of the policy regime.

- If the experience of the last 20 years is a guide – a period that includes a wide range of sizeable economic shocks – we would expect the major economies outside Japan to continue to enjoy unusually stable conditions, albeit not as "nice" as the last decade.
- A return to 1970s style shocks would disturb all the major regions and materially increase severe recession risk. A continuation of stable economic conditions would appear to depend on the presence of sound counter-inflation policies and an absence of extreme geopolitical or natural disasters.

A brief history of volatility

The history of business cycles can be conveniently summarised using a measure of volatility of economic growth and inflation. Growth is measured by the annual percentage change in the gross domestic product expressed in volume terms; inflation is measured by the annual percentage change in the economy-wide measure of prices. Data are taken from authoritative sources. National official sources are used for post-World War II US and UK data; otherwise we rely, in addition, on Feinstein (1972); Johnston and Williamson (2003); Maddison (2003); Mitchell (1982, 1998) and the OECD Economic Outlook database and its updates. We use the sample measure of standard deviation to gauge the typical scale of the ups and downs of growth and inflation around their averages. For our purposes, only unimportant details and not the broad picture would be affected were we to use other measures of volatility, such as the variability of the "output gap" or quarterly rates of growth and inflation.

Tables 1 and 2 divide the last 50 years into four periods – first, the 20 years from the end of the Korean War in the early-1950s to the growth climacteric of 1973, a period often referred to as a "Golden Age"; second, the subsequent turbulent decade of large oil price and other shocks until 1983; third, the next decade of marked disinflation and, fourth, the benign decade ending in 2003. The choice of 1983 and 1984 as dividing years is important for a particular reason. Applying sophisticated statistical methods to a wide variety of economic measures, a library of research has concluded that stability broke out in America precisely 20 years ago. Elsewhere, volatility breaks, estimated using similar techniques, might have occurred earlier as well as later, as Table 3 shows.

The simple estimates in Table 1 suffice to bring out the main changes in the volatility of growth. In the US, growth volatility in the last decade was half that of the Golden Age up to 1973, and less than half the volatility of the turbulent decade in the 1970s and early-1980s. Large reductions in growth volatility are seen in most of the other major economies shown in Table 1. Comparing the last decade with the Golden Age, growth volatility has fallen by between 40% and 60% in the major economies except France, and all of them are less volatile compared with the decade ending in 1983. The changes in inflation volatility are more dramatic still. Compared with the Golden Age (which includes the period of sharply rising inflation from the late-1960s onwards), inflation volatility in the major economies has fallen by between 60% and 80% in the last decade.

Table 1: Growth volatility

%	1954-1973	1974-1983	1984-1993	1994-2003
United States	2.5	2.8	1.9	1.2
Germany	2.4	2.0	1.9	1.0
France	1.2	1.4	1.6	1.2
Italy	1.5	2.7	1.4	0.9
United Kingdom	1.8	2.2	2.0	0.8
Japan	2.4	1.9	2.0	1.5

Source: see text. Standard deviations of annual real GDP growth

Table 2: Inflation volatility

%	1954-1973	1974-1983	1984-1993	1994-2003
United States	1.6	1.9	0.7	0.4
Germany	1.9	1.2	1.1	0.8
France	2.5	1.2	1.6	0.6
Italy	3.0	2.4	2.2	1.2
United Kingdom	2.4	6.0	1.7	0.7
Japan	2.7	5.4	1.0	0.9

Source: see text. Standard deviations of annual GDP price inflation

Table 3: Timing of growth volatility reduction

Study/economy	Mills & Wang	Smith & Summers	van Dijk, Osborn & Sensier*
United States	1984	1984	1984
Canada	late-1970s	1992	1984
Australia	n.a.	1984	n.a.
Germany	1974	early-1970s, ? after unification	1994**
France	1979**	n.a.	1989
Italy	1982	n.a.	1988
United Kingdom	1993	1982 or 1992	1990
Japan	1976	1975 , 1997↑	1992↑**

Source: Mills and Wang (2000); Smith and Summers (2002); van Dijk, Osborn and Sensier (2002) * industrial production; others refer to GDP. ↑ volatility increase ** insignificant. These studies use sophisticated statistical procedures (for example, Markov switching models) to estimate volatility break points and their significance.

In the light of Blanchard and Simon's (2001) interesting contention that US growth volatility is subject to a trend decline, we examined the ten-year trailing standard deviations of growth and inflation of the US and 14 other industrial economies and, in each case, tested for the significance of a time trend. The test allowed for the fact that adjacent ten-year trailing measures have nine years of observations in common. Regressions, run from 1960, included observations on growth and inflation since 1951.

Of the 15 economies, we found evidence in seven, including the US, Germany and Japan, of a declining trend in the volatility of growth. Inflation volatility appears to trend downwards in five economies, including France and Spain. In the majority of cases, however, the evidence rejects the idea of trend decline in growth or inflation volatility.

There is an important proviso. Interpretation of the movements in growth volatility shown in Table 1 needs to make allowance for changes in the average rate of growth. A fall in growth volatility should lessen the likelihood of severe recession and lead to longer expansions – but this will only be so if the average (or "trend") rate of growth does not decline at the same time. (The estimates in Table 3 are appropriately based on models that can allow for movements in the average growth rate.)

Table 4: Frequency of severe recession

%	1954-1973	1974-1983	1984-1993	1994-2003
United States	10	40	10	0
Germany	5	20	10	10
France	0	10	10	0
Italy	0	10	10	0
United Kingdom	0	40	10	0
Japan	0	10	0	20

Source: see text. Number of years when 0 ≥ GDP growth, % of number of years in period

To illustrate the combined effect of changes in the average rate of growth and in growth volatility, Table 4 examines the peacetime history of severe recessions. A severe recession is defined as any year in which GDP falls or fails to grow. The table records the number of severe recession years expressed as a percentage of the number of years in each period.

The results show that the Golden Age was largely free of severe recessions measured in this simple fashion, though it is salutary to be reminded that US GDP fell in two years (1954 and 1958) despite a high trend rate of growth that exceeded 3½% a year. The standard deviation of growth was 2.5%, however. With some poetic licence, one could describe zero US growth during this period as an infrequent but not rare "1½ standard deviation event". Severe recessions became far more frequent across the major economies in the turbulent 1970s, a reflection of declining average rates of growth and high growth volatility. By contrast, the last decade has witnessed a decline in the incidence of severe recessions in all the major economies except Japan.

In the US, lower growth volatility combined with an average growth rate since 1994 in excess of 3% a year has made zero growth a rare "2½ standard deviation event". In Europe, the improvement has also been marked. Of the 11 European economies in our set of data, five have experienced the same incidence of severe recessions compared with the 1954-1973 period, four (including Spain) have a better record while two (including Germany) have a worse record.

Japan is the main exception. Here the benefit of the reduction in growth volatility has been offset by the impact of a markedly lower average rate of growth of less than 1½% a year. Japan has experienced two years of falling GDP in the last decade and has been close to stagnation on two other occasions. This deterioration is also reflected in the sophisticated volatility estimates shown in Table 3.

Against this background, it would be difficult to interpret the decline in growth volatility seen in the last decade as part of a secular improvement across the industrial world. In most cases, there is no evidence of a favourable trend over the last 50 years, and in two main economies (Japan and Germany) where a trend may exist, a lower average growth rate has led to a higher incidence of severe recession.

America appears to be different, however, in keeping with the view of Blanchard and Simon (2001). The US has experienced a substantial decline in growth volatility, though opinions differ on whether the decline was once-and-for-all or part of a trend (see the contrasting views of Stock and Watson (2002) and van Dijk, Osborn and Sensier (2002)). In addition, the US has enjoyed a high (and recently improving) trend rate of growth, longer periods of expansions and an absence of severe recessions.

The much longer-term history offered in Table 5 provides another useful perspective. The table covers the history of growth volatility during the period of the International Gold Standard, roughly from the early-1870s to the outbreak of World War I, the subsequent 40 years of wars, depression and reconstruction, and the peacetime period of the last 50 years.

Table 5: Growth volatility – the long view

%	Gold Standard 1871-1912	Wars & depression 1913-1953	------------------ Peacetime ------------------ 1954-2003	1954-1993	1994-2003
United States	4.2	7.6	2.3	2.5	1.2
Germany	2.3	13.4	2.6	2.7	1.0
France	4.5	12.6	2.0	2.0	1.2
Italy	4.1	9.2	2.3	2.3	0.9
United Kingdom	2.2	4.5	1.9	2.1	0.8
Japan	5.2	10.2	3.8	3.6	1.5

Source: see text Standard deviations of annual real GDP growth

It should go without saying that the quality of the data deteriorates as one reaches further back in time; in particular, historians have fiercely debated the accuracy of the US figures (see, for example, the exchange between Balke and Gordon (1989) and Romer (1987, 1989)). The pattern of volatility is sufficiently widespread, however, that a broad-brush conclusion seems possible. Apart from the 1970s, it appears that most economies enjoyed more stability after World War II, an interpretation supported by the sophisticated tests performed by Bergman, Bordo and Jonung (1998).

Table 6: Global growth volatility

%, simple average	1954-1973	1974-1983	1984-1993	1994-2003
World	4.3	5.3	4.3	3.0
of which:				
15 industrial economies	2.1	2.1	1.8	1.2
91 other economies	4.7	5.9	4.7	3.3
of which:				
Africa	4.7	6.5	4.4	3.7
Latin America	3.4	4.9	3.6	3.0
Asia & Middle East	5.6	5.6	5.8	3.1

Source: see text Standard deviations of annual real GDP growth

So far, the focus has been on the performance of individual economies but it is also relevant to have regard to the performance of industrial and other economies considered collectively. As a guide to global patterns over the last 50 years, Table 6 records growth volatilities averaged across 106 economies, 15 main industrial economies and 91 others, mostly developing and emerging. Data on the latter are drawn from Maddison (2003) and the IMF World Economic Outlook database.

Although statistics of variable quality need to be interpreted with care, two features stand out. Not surprisingly, developing and emerging economies are more volatile than industrial economies, a fact well documented by Easterly, Islam and Stiglitz (2000). Rather more surprising is the general reduction in growth volatility seen in the last decade across all the major global regions. Compared with the Golden Age, global growth volatility since 1994 has fallen by 30%.

These simple across-economy averages, which give equal weight to the volatility of the smallest and largest economy, may not be the most useful, however. The performance of multinational companies or of internationally diversified equity portfolios, for example, would typically be more closely tied to the volatility of the main industrial economies with volatilities weighted by size.

Table 7 performs this calculation by constructing an industrial world group, the G15, the summation of the gross domestic products in constant purchasing-power US dollars of 15 main industrial economies. The table compares the variability of GDP growth of the G15 with the simple across-economy average given in Table 6. Variability on both measures has been lower in the last decade than in the Golden Age. The more striking fact is that the variability of G15 growth has been only two-thirds the size of the simple across-economy average in every period shown save the 1970s and early-1980s.

It is worthwhile exploring in more detail the source of the difference between these two measures of industrial world volatility. The difference arises, first, as already noted, from the weights given to individual economies' experience and, second, from the degree to which those experiences are shared. This raises the question of the correlation between growth rates. Were growth rates uncorrelated, individual economies' particular experiences would tend to average out, reducing the variability of industrial world (G15) growth as a whole. Growth synchronisation would have the opposite effect. The fact that the variability of growth of the G15 has remained at two-thirds of the simple across-economy average suggests that economies' growth rates have *not* become more correlated over time.

Table 7: Industrial world (G15) growth volatility

%	1954-1973	1974-1983	1984-1993	1994-2003
a) simple average	2.1	2.1	1.8	1.2
b) group average	1.4	1.8	1.3	0.8
Memo:				
b) as % of a)	68	85	69	67

Source: see text Standard deviations of annual real GDP growth

The same point is made more precisely in Table 8, which divides the variability of G15 growth into two parts, one arising from the growth variability of America, Europe and Japan, weighted by size of region, the other arising from the degree of regional growth synchronisation. The results show that the contribution of synchronisation was no larger in the last decade than in the 1950s and 1960s. Only during the 1974-1983 interval did the contribution of synchronisation increase. Other research supports this conclusion. Doyle and Faust (2003), for example, find no evidence of a statistically significant change in growth correlations from the 1980s to the 1990s, even between members of the Euro area or between the US and Canada.

Table 8: G15 growth variability decomposition

%	1954-1973	1974-1983	1984-1993	1994-2003
Group average	1.4	1.8	1.3	0.8
contribution of:				
individual regions	1.1	1.0	0.9	0.6
synchronisation	0.3	0.8	0.4	0.3

Source: see text. Standard deviations of real GDP growth. To calculate the split, G15 growth was recomputed as the fixed-weighted sum of growth rates of an "American" region (comprising US, Canada, Australia), Europe and Japan. The variance of the G15 growth rate was decomposed into the sum of fix-weighted variance ("individual regions") and covariance ("synchronisation") terms and the results apportioned to total standard deviation. Sum of parts may not equal the total due to rounding error.

This feature is puzzling for those who expected the process of "globalisation" - increased international trade, growing international production, deeper financial market integration – to lead to a dominant, global business cycle. Studies have shown that increased trade and capital market integration raise growth correlations and some sophisticated analyses reveal an important common component in the volatility of growth of the major economies (see, for example, Imbs (2004); Kose and Yi (2002); Kose, Otrok and Whiteman (2004)). But the bald facts do not show a rising degree of cycle synchronisation.

This is not a new puzzle. The years corresponding to the gradual adoption of the International Gold Standard between around 1870 and the outbreak of World War I provide another example of globalisation, when international trade grew rapidly and labour and capital moved comparatively freely between countries. Yet as Bordo and Helbling (2003) document, economies were highly decoupled during this period. A repetition of the calculation in Table 8 shows that the contribution of regional synchronisation to G15 growth volatility under the Gold Standard was close to zero. Panic (1992) argues that countries varied tariff levels during this period to immunise themselves from shocks.

A number of explanations have been offered to solve the more recent "globalisation puzzle". Krugman (1993), for example, reasons that specialisation fostered by international trade could make economies more vulnerable to shocks that affect only their industries and no one else's. The analysis of Heathcote and Perri (2002, 2003) suggests that increased financial market integration might have enabled the US to enjoy a technology-driven investment boom in the late-1990s larger than would otherwise have been the case, at the expense of investment spending overseas - a form of international "crowding-out".

Another explanation is that regions in the 1990s were subject to large specific shocks and surprises – the US productivity revival, European monetary union, Japanese debt deflation – that encouraged cycle decoupling (see, for example, Helbling and Bayoumi (2003); Kose, Otrok and Whiteman (2004); Martin (1997)). By contrast, large common shocks, such as the two massive oil price hikes, may have promoted a (temporary) synchronisation of growth rates in the 1970s and early-1980s. Stock and Watson (2003a) argue that cycle volatility and growth correlations would increase considerably were world shocks of the 1970s kind to re-appear.

Explaining stability

What, then, explains the outbreak of stability? Suggestions fall into three camps: first, structural changes that promote the self-stabilisation of economies; second, changes in the conduct of policy and, third, changes in the volatility of shocks that buffet economies. This demarcation is not watertight, of course, since both structure and shocks may depend on the policy regime. There is also little agreement amongst researchers about the main forces at work. We begin with a brief review of frequently suggested structural explanations before turning to more promising lines of inquiry.

Sectoral shifts

In his 1960 Presidential address to the American Economic Association, Arthur Burns argued that a trend decline in US output volatility was in train, partly thanks to the shift away from volatile manufacturing towards a more stable service economy. Although seemingly correct about the trend decline in volatility, the sectoral-shift explanation of changing volatility does not stand up to scrutiny.

A simple test, performed, for example, by McConnell and Perez-Quiros (2000), involves the recalculation of the volatility of GDP growth holding constant the shares of different industries. Were sectoral shifts important, one would expect to find a much smaller fall in the volatility of GDP growth calculated with fixed shares than with variable shares. In the US this is not the case because the volatility of output fell across the board.

Stock and Watson (2003b) extend the calculation to other major economies. Table 9 shows that the sectoral shift view "works" only in the case of Germany, where the fall in volatility is anyway compromised by the decline in trend growth. In Italy and Japan, the calculations go the "wrong" way. Although a high proportion of a small fall in growth volatility, the absolute impact in the UK is tiny.

Table 9: Impact on growth volatility of sectoral shifts

%	US	Germany	France	Italy	UK	Japan
volatility change	-0.0	-0.2	-0.0	0.1	-0.1	0.2
% of variance change	-8	-24	-9	9	-62	12

Source: Stock and Watson (2003b). First row shows the change in the standard deviation of GDP growth attributed to sectoral share changes, comparing 1960-1983 with 1984-1996. Row 2 shows the fall in growth variance due to sectoral share shifts as a % of the observed change in growth variance. To aid comparison with other tables here, the authors' results have been recalculated in terms of standard deviations (row 1) and a sign convention changed.

Inventory management

McConnell and Perez-Quiros (2000) and Kahn, McConnell and Perez-Quiros (2002) argue that the improved control of inventories – such as "just-in-time" techniques – fostered stability by enabling US companies better to smooth their production in the face of surprise changes in demand. Output volatility thus fell, the authors contend, in the face of continuing volatility of sales.

Again, the facts do not oblige. Several studies have shown that the volatility of sales also fell, possibly concurrently with the fall in the volatility of US output (see, for example, Ahmed, Levin and Wilson (2004); Herrera and Pesavento (2003); Kim, Nelson and Piger (2003)). Moreover, if inventory control were key, one would expect to find a fall in the volatility of output that exceeded any fall in the volatility of sales. McCarthy and Zakrajšek (2002) and Stock and Watson (2002) both find against this proposition; in particular, the latter show that any disproportionate fall in US output volatility relative to sales volatility seen in quarter-to-quarter figures disappears at annual frequencies. Extending the analysis to examine the volatility record of seven major economies, Barrell and Gottschalk (2004) conclude that "Inventories appear to have little explanatory power".

Financial market de-regulation

It is sometimes conjectured that financial market liberalisation may have fostered stability. Abolition of credit controls and the de-regulation of the mortgage market, in particular, should have enabled consumers better to smooth shocks to their income. But as Blanchard and Simon (2001) argue, de-regulation has also made it easier for consumers and companies to adjust spending to achieve their desired holdings of consumer durables and capital, adding to spending volatility. Pro-cyclical lending policies – banks turning the credit tap on in booms and off in recessions – would have the same effect.

Inflation behaviour

A more promising line of enquiry concerns the changing behaviour of inflation. The rise and fall in growth volatility over the last 50 years coincides with a rise and fall in inflation, which may in turn have led to changes in the way economies respond to shocks and surprises. Compared with the 1970s, inflation appears to have become less self-feeding and less responsive to changes in output. The net effect on economic volatility is unclear, however.

Inflation's self-feeding tendency – sometimes referred to as its degree of "persistence" - can be measured by the size of the coefficient (or sum of coefficients) on past inflation in an inflation regression. The smaller the coefficient, the smaller would be the effect of an inflation shock today on future inflation. Proper estimation of the persistence phenomenon is difficult and contentious (compare, for example, Cogley and Sargent (2001) with Pivetta and Reis (2003)). Nevertheless, many studies, most focussed on the US, document a decline in inflation persistence as inflation subsided[6].

Taylor (2000), for example, estimates that the inflation persistence coefficient in the US declined from 0.94 to 0.74 comparing the periods 1960 to 1979 with 1982 to 1999. Brainard and Perry (2000) estimate that the US coefficient rose from 0.58 in 1965 to 0.80 in 1980, subsequently falling to 0.41 in 1998. Kim, Nelson and Piger (2003) note "a large drop in persistence" in the US after 1979, with the persistence coefficient falling from 0.93 to 0.72. For Canada and the UK respectively, Ravenna (2000)

[6] See, for example, Akerlof, Dickens and Perry (2000); Batini and Nelson (2001); Benati (2002); Brainard and Perry (2000); Cogley and Sargent (2001, 2003); Erceg and Levin (2003); Kim, Nelson and Piger (2003); Ravenna (2000); Taylor (2000).

and Batini and Nelson (2001) document large falls in inflation persistence during the 1990s. The evidence is not all one way, however. Batini (2002) finds little change in inflation persistence in the Euro area, while Levin and Piger (2003) conclude that the persistence of inflation in most industrial economies during the 1984-2002 interval was generally low (though Japan was an exception).

Broadly consistent with this state of play, the second and third columns of Table 10 show our simple estimates of inflation persistence in the US, UK and Japan and in the major economies that comprise today's Euro area. Estimates are shown for a high inflation era (specifically, the years 1968 to 1983) and a low inflation era (the years since 1984). In the ten economies represented, the average inflation rate fell by about two-thirds between these periods. The table records a concurrent fall in inflation persistence in each region, which, in line with other evidence, is most marked in the US and UK.

Table 10: Inflation characteristics

	inflation persistence		**output sensitivity**	
inflation period	**high**	**low**	**high**	**low**
United States	0.94	0.37	0.50	0.19
Euro area	0.38	0.28	0.59	0.29
United Kingdom	0.96	0.34	0.73	0.42
Japan	0.76	0.62	0.30	0.19

Source: authors' calculations based on SURE regressions in high (1968-1983) and low (1984-2003) inflation periods with inflation a function of lagged inflation and a lagged measure of the output gap (the percentage excess of GDP over trend GDP, the latter derived using a Hodrick-Prescott filter). Regressions include trend and intercept shifts, emphasised by Coenen and Wieland (2002) and Levin and Piger (2003), and shock dummies in the case of the UK and Japan during the high inflation period. The appendix gives more details.

The cause of the downshift in persistence is much debated. New Keynesian models rely on the presence of "menu costs": it may be administratively costly for firms to amend their prices or for wage bargainers to acquire inflation protection. As a result, their reaction to inflation may be subdued when inflation is low but become more aggressive when inflation is high, a shift of behaviour predicted by Rowthorn (1977) and re-examined by Akerlof, Dickens and Perry (2000).

A second possibility is that expectations of inflation may have become grounded, thanks to the increased credibility of inflation targets and central banks. Erceg and Levin (2003), for example, argue that inflation expectations are driven by private agents' forecasts of the central bank's inflation target; ergo, inflation persistence "varies with the stability and transparency of the monetary policy regime".

As Bean (2003) documents, the same forces that might account for the fall in inflation persistence could explain the second apparent change in inflation's behaviour - its more limited response to changes in output. This is tantamount to a flattening of the slope of the short-run Phillips curve that relates inflation to unemployment. The estimates given in the final two columns of Table 10 reveal precisely this tendency, though its true nature is the subject of ongoing debate. The reduced sensitivity of inflation to output may be a genuine phenomenon or it may reflect shifts in productive potential (compare, for example, Mourougane and Ibaragi (2004) with Staiger, Stock and Watson (2001)).

A fall in inflation persistence and a flattening of the Phillips curve, both resulting from a regime of low inflation and more grounded inflation expectations, should be auspicious for stability. Inflation shocks would prove less damaging, easing the problems faced by policy makers who aim to contain inflation while also stabilising output. The appendix shows formally how a low inflation regime could lead eventually to lower volatility not only of inflation but also of output, by an amount dependent on the volatility of shocks, policy preferences and the inflation process itself.

There is a qualification, however. A flattening of the Phillips curve that occurred for other reasons, leaving the degree of inflation persistence unchanged, would not necessarily make policy makers' job any easier. The impact on growth and inflation volatility would depend on the type of shock to which the policy maker had to respond. With a flatter Phillips curve, output shocks would have a smaller effect on inflation, requiring a more modest interest rate response from the central bank. Growth variability could fall. But in the face of a direct inflation shock, the smaller response of inflation to output would require a larger interest rate reaction and a larger sacrifice of output. Growth variability could rise. These propositions are explained more formally in the appendix.

Better policy

In addition to its impact on inflation, changes in the conduct of economic policy may well have affected economic volatility in more direct ways. In particular, the very long-term decline in volatility portrayed in Table 5, as well as the periods of extreme turbulence, may be partly attributed to the gradual development of macroeconomic policy and policy makers' long and variable learning curve.

In the nineteenth century, monetary policy was constricted in countries tied to the Gold Standard (and, in effect, to a dominant sterling standard): only by chance were interest rates suited to the needs of the domestic economy. Although constrained by the attempts to go back on Gold, monetary policy found a more independent voice in the 1920s, for good and ill. The scale of the Great Depression is widely attributed to errors from which today's central bankers have learned. The implementation of effective lender of last resort facilities, deposit insurance and financial safety nets are part of that legacy.

As regards fiscal policy, use of the budget to regulate demand was not even a practical proposition one hundred years ago. According to Romer (1999), US taxes and government spending were "so small that plausible variations in fiscal policy could neither cause nor dampen significant fluctuations". After World War II, a commitment to full employment and the growth of the welfare state gave rise to automatic income and demand stabilisers – changes in cyclically-sensitive tax receipts and welfare spending – as well as to more active fiscal policy.

The latter's track record is patchy; in the US case, for example, Auerbach (2002) concludes "There is little evidence that discretionary fiscal policy has played an important stabilising role in recent decades". The automatic stabilisers may have been more effective. In a study of 20 major economies, Fatás and Mihov (2001) find that ".. a one percentage point increase in government spending relative to GDP reduces output volatility [standard deviation of GDP growth] by eight basis points", results that in the authors' view "lend support to the traditional Keynesian view of automatic stabilisers." In the US, Cohen and Follette (1999) note that automatic stabilisers have been "quietly doing their thing".

Changes in policy makers' understanding of the world also help to explain the rise and fall in inflation, and the associated volatility, during the last 50 years. In the 1960s and 1970s, US and UK policy makers attributed the rise in inflation to the effects of militant workers and soaring commodity prices – a "cost-push" view of inflation. Nelson (2004), amongst others, argues that this belief made policy makers reluctant to use monetary policy as a counter-inflation tool: demand management was deemed to be too blunt and costly an instrument.

One result was resort to direct controls over prices and incomes. A second was a failure better to measure the true degree of spare economic capacity, a problem aggravated by the post-1973 slowdown in trend growth. A third was a failure to raise interest rates in an appropriate fashion. In the 1970s, real interest rates – nominal rates less inflation – were too low and too unresponsive to inflation. As Taylor (1993, 1999) notes, failure to raise interest rates more than proportionately as inflation rose would lead to a perverse fall in real interest rates that, in turn, would add to inflationary pressure. The "Taylor Rule" thus requires nominal interest rates to move more than in proportion to inflation shocks.

Most statistical depictions of monetary policy show that policy makers did indeed act perversely during the Great Inflation but changed course following the appointment of Paul Volcker as Federal Reserve chairman in 1979[7]. Volcker's appointment coincided with the second major oil price shock and widespread fears of explosive inflation, events that marked the beginning of a new monetary policy regime, in the US and elsewhere, which has gradually evolved. Consistent with this history, the majority of response coefficients linking nominal interest rates to inflation shown in Table 11 moves from well below unity in the period of high inflation to above unity subsequently.

[7] See, for example, Boivin and Giannoni (2002); Clarida, Gali and Gertler (2000); Cogley and Sargent (2001, 2003); Judd and Rudebusch (1998); Nelson (2000); Stock and Watson (2003b); Taylor (1999). Exceptionally, Orphanides (2004) argues that US policy makers always raised interest rates aggressively in response to *expected* inflation but overestimated the economy's spare capacity in the 1970s. But Nelson (2004) argues that expectations of inflation were systematically too low in the 1970s, giving rise to a weak interest rate response to actual inflation.

Table 11: Interest rate long-run response to inflation

Region	United States		Euro area		United Kingdom		Japan	
inflation regime	High	Low	high	low	high	low	high	low
Clarida et al. (1998)	-	1.79	-	1.31*	-	-	-	2.04
Clarida et al. (2000)	0.83	2.15	-	-	-	-	-	-
Gerdesmeier & Roffia	-	-	-	1.93	-	-	-	-
Kamada & Muto	-	-	-	-	-	-	-	0.33
Judd & Rudebusch	0.85	1.62**	-	-	-	-	-	-
Martin and Rowthorn	0.44	1.54	0.62	1.63	0.37	1.19	0.37	1.09
Nelson	-	-	-	-	0.34**	1.27	-	-
Taylor	0.81	1.53	-	-	-	-	-	-

Source: Clarida, Galí and Gertler (1998, 2000); Gerdesmeier and Roffia (2003); Kamada and Muto (2000); Judd and Rudebusch (1998); Martin and Rowthorn (this paper); Nelson (2000); Taylor (1999). * Bundesbank
** average of two sub-periods. Since estimation methods and sample periods vary considerably, we assign to high and low inflation regimes regression coefficients that appear representative of each study. The authors' estimates are based on a simple Taylor Rule specification – see appendix.

Monetary policy developments may have promoted stability of inflation but the impact on output volatility is less clear, as Cecchetti and Ehrmann (1999) emphasise. Unlike shocks to output, shocks to inflation require policy makers to choose between stabilisation of output and the stabilisation of inflation. An oil price shock, for example, would tend to raise prices and depress output – and policy may aggravate the latter while repressing the former. Over time, a growing preference for stable inflation might have been achieved at the expense of greater output volatility.

Shocks and surprises

A final possibility is that the outbreak of economic stability is just good luck. Many claim that the volatility of growth and inflation in the 1970s arose from great misfortune – such as huge oil price increases and the coincidental slowdown in trend growth. Conversely, less pronounced shocks over the last 20 years are deemed to have contributed to the decline in economic volatility.

Others, like Taylor (1998), reject this account on the grounds that shocks continued unabated after the mid-1980s. Examples include disruptive currency movements; the US savings and loans crisis; large oil price changes; Britain's late-1980s housing boom and bust; the European exchange rate mechanism debacle; massive stock market bubbles; Europe's monetary union. This debate cannot be resolved by the citation of lists of events, however. Some measure of the volatility of shocks is required.

Based on our simple models, Table 12 offers tentative estimates of the standard deviation of output and inflation shocks in the high inflation period before 1984 and in the years subsequently. The estimates suggest that shocks have indeed become more subdued over the last 20 years. The variability of output and inflation shocks has fallen on average by around 35% and 55% respectively, with the largest falls occurring in the UK and Japan and the smallest (possibly insignificant) occurring in the Euro area.

Table 12: Shock variability

%	---------- output shocks ----------		---------- inflation shocks ----------	
inflation regime	high	low	high	low
United States	1.8	1.2	1.1	0.4
Euro area	1.2	1.0	0.6	0.4
United Kingdom	1.9	1.0	4.6	0.9
Japan	2.4	1.2	3.8	0.7
G10	1.3	0.9	0.8	0.3

Source: authors' calculations Standard deviations of output and inflation shocks in high (1968-1983) and low (1984-2003) inflation periods. G10 shows the standard deviations of the fix-weighted sum of regional shocks. The "shocks" are the residuals from output gap and inflation regressions adjusted to include the impact of shock dummies in the high inflation period. For each region, output gap residuals are taken from SURE regressions over the 1968-2003 period relating the output gap to the lagged output gap, a measure of the lagged real short-term interest rate and the lagged change in the budget-deficit-to-GDP ratio – see appendix.

Accounting for stability

One way to ascertain the relative importance of the forces that may have contributed to greater economic stability is to conduct counterfactual exercises. These exercise involve imagining how today's economies would cope with yesterday's shocks and, conversely, how yesterday's economies would cope with today's shocks and then examining the differences.

Many studies have undertaken such comparisons, despite the severe difficulties. The counterfactuals rest on the strong assumption that the nature of the economy is separable from the shocks it faces. And the results are sensitive to the usual problems of estimating abstract, often highly simplified, economic models, made worse in this case by the short period of years from which it is possible to detect changes of behaviour. "Shocks" are identified with the residuals from such models – so "bad" models inevitably attribute most of the volatility of GDP and inflation to shocks rather than to structure. However, the counterfactual method is useful if treated as an accounting exercise in broad orders of magnitude.

At a general level, our concern is to account for the observed change in economic volatility between two periods. One way to proceed involves the running of numerous simulations of a model of an economy when it is repeatedly subject to shocks that are, in some sense, characteristic of each period. These pretend shocks might be manufactured, for example, by taking samples of shocks from an (assumed) probability distribution. Ahmed et al., (2004); Buch et al., (2002) and Stock and Watson (2002) use an analytical equivalent of this procedure to examine how economic performance would change were economies subject to period-1 type shocks instead of period-2 type shocks.

An alternative method, deployed, for example, by Judd and Rudebusch (1998) and Stock and Watson (2003b), uses not pretend shocks drawn from a distribution but rather the "actual" shocks observed in each period, a procedure that may well be preferable when sample periods are short. A further advantage is that a model simulated with "actual" shocks over the period from which those shocks were estimated will exactly replicate the history of the period, as a matter of identity. This feature enables a more precise decomposition of the observed change in volatility of growth and inflation.

Again at a general level, we can identify three reasons why volatility might change between two periods. The first concerns the position from which the economy starts – its "*initial conditions*". Volatility could fall were an economy initially out of balance in the first period but in balance at the start of the second period, a consideration given scant attention in previous studies[8]. The second contributor to changed volatility reflects changes in *economic behaviour* (for example, of inflation or of policy), driving forces that are often referred to collectively as an economy's "propagation mechanism". The third contribution comes from changes in *shocks* that perturb the economy.

These three contributors to changed economic volatility give rise to multiple counterfactuals and comparisons, as Table 13 illustrates. Each counterfactual here represents different combinations of the (earlier) period 1 and (later) period 2 contributors (initial conditions, economic behaviour or shocks). "Counterfactuals" A1 and A5 are special in that they use own-period contributors and therefore exactly replicate the history of their respective periods. The observed change in volatility is measured by subtracting the variance of A5 from the variance of A1, a difference that can be attributed to multiple combinations of the three contributors looking both backwards and forwards in time.

Table 13: Counterfactual volatilities

Sets	A1	A2	A3	A4	A5	A6	A7	A8
Initial conditions	2	2	2	2	1	1	1	1
Economic behaviour	2	2	1	1	1	1	2	2
Shocks	2	1	2	1	1	2	1	2

Note: Figures refer to periods 1 and 2

For example, the role of changed behaviour can be investigated by backwards applying period 2's behaviour to period 1's initial conditions and shocks (counterfactual A7) or by forwards applying period 1's behaviour to period 2's initial conditions and shocks (counterfactual A3). A7 less A5 gives the impact of the change in behaviour holding constant period 1's initial conditions and shocks while A1 less A3 shows the impact of the change in behaviour holding constant the initial conditions and shocks of period 2. The differences between counterfactuals A8 and A6 and between A2 and A4 offer further alternatives holding constant different mixes of initial conditions and shocks: either period 1 initial conditions with period 2 shocks or period 2 initial conditions with period 1 shocks.

[8] For example, the contribution formulae in Stock and Watson (2003a) ignore initial conditions.

To account for the change in volatility, it is logically necessary to consider all backward-forward possibilities for each contributor. A further complication arises from the fact that the impact of a change in economic behaviour (unlike that of the other contributors) interacts with starting conditions and shocks, creating an adding-up problem. For example, the sum of A4 less A5, A7 less A5 and A6 less A5, respectively the impacts in period 1 of changed initial conditions, changed behaviour and changed shocks, will in general not equal A1 less A5. In the appendix, we describe formulae that exhaust backward-forward comparisons, avoid double counting, apportion interaction effects in a symmetric fashion and, by identity, exactly account for the observed change in economic volatility.

Table 14 presents our estimates of the forces contributing to the change in growth and inflation volatility between the periods 1968-1983 and 1988-2003, each period being of an equal length determined by the shorter high-inflation period. The results show the attributed decline in the variance of growth and inflation expressed as a percentage of the change in variances between the two periods. A minus sign indicates a change that produces greater stability.

The results paint the following broad picture:

- As regards the fall in growth variability, changed shocks played the dominant role in the US and UK while changed economic behaviour played the dominant role in the Euro area and Japan.

- As regards the fall in inflation variability, changed economic behaviour played the greater role in the US and Euro area; changed shocks played the dominant role in the UK and Japan.

Table 14: Stability contributors - summary

% of change in variance	Initial conditions	Economic Behaviour	Shocks & surprises
Growth			
United States	-2	2	-100
Euro area	12	-91	-21
United Kingdom	14	-7	-107
Japan	15	-93	-21
Inflation			
United States	-6	-58	-36
Euro area	34	-153	19
United Kingdom	18	-26	-92
Japan	-19	-18	-63

Source: authors' calculations Total of contributions is –100%, subject to rounding error. Calculations in terms of the output gap show a pattern similar to that given here for growth.

Historical circumstances have a considerable bearing on these results. For example, in the early-1990s, the Euro area and Japan were coping with excess demand, the result of German unification and Japan's previous property bubble. By contrast, the US and UK were in recession. In these circumstances, a 1970s-style regime of low real interest rates – that is, forwards applying period-1 policy behaviour to period-2 conditions - would have further disrupted the Euro area and Japan but would have helped stabilise activity in the US and UK, albeit with adverse implications for inflation. As a result, the change in economic behaviour between high and low inflation periods was beneficial to the Euro area and Japan but contributed little to the observed fall in growth volatility in the US and UK, even though the behaviour changes in these economies are generally auspicious for stability[9].

Looking in more detail, one might wish to divide the contribution of behaviour in Table 14 into component parts – those attributable in our models to the changed behaviour of inflation, interest rates and fiscal policy. But this division can be misleading. Monetary policy aided stability both directly, as the response of interest rates changed, and also indirectly, through the effect on inflation's behaviour.

[9] One can contrast this result with the calculation of (asymptotic) variances implied by the analytical procedure of, for example, Stock and Watson (2002). US and UK output gap asymptotic variances fell by an infinite amount between high and low inflation periods, the consequences of instability in the high inflation era. The instability arises from the combination of a very high degree of inflation persistence and the below unit coefficient on inflation in the interest rate equation. In technical terms, the US and UK high inflation models have an explosive root: the dominant eigen values are 1.02 and 1.07 respectively. This is a nice illustration of the pitfalls of using asymptotic variances to make inferences about changed economic performance over short time periods.

Other researchers, including Stock and Watson (2003b), count only the changed interest rate response and arguably understate monetary policy's role.

The detailed split given in Table 15 shows that:

- The changed behaviour of inflation reduced growth volatility, especially in Japan and in the Euro area, and reduced inflation volatility significantly in all regions except Japan (where changed shocks played the dominant role).
- Changes in interest rate policy reduced growth volatility everywhere, curtailed inflation volatility in the Euro area but raised inflation volatility in the US and UK, possibly reflecting a policy trade-off between growth and inflation stabilisation.
- Changes in budget policy promoted stability in Japan but played a small role elsewhere.

Adding together the contributions of changed inflation and changed interest rate behaviour, the table suggests that monetary policy made a significant contribution not only to the reduction in the level and volatility of inflation but also to the reduction in growth volatility. The largest impact is in the Euro area where 72% of the reduction in growth volatility is attributed to the general effects of monetary policy. In Japan and the UK, our figures for monetary policy's role are 59% and 15% respectively. The smallest effect occurs in the US (7%) though this may well be an understatement; several years of Volcker's reforms are included in the earlier period used in our comparisons.

Table 15: Stability contributors – types of behaviour

% of change in variance	------------ Contribution arising from changes in the behaviour of ------------				
	Inflation rate	Interest Rate	Monetary policy **	Budget policy	All *
Growth					
US	-1	-7	-7	9	2
Euro area	-23	-49	-72	-19	-91
UK	-4	-11	-15	8	-7
Japan	-20	-38	-59	-35	-93
Inflation					
US	-93	26	-67	9	-58
Euro area	-89	-57	-147	-6	-153
UK	-56	37	-19	-7	-26
Japan	-5	-4	-9	-8	-18

Source: authors' calculations * sum of third & fourth columns, equal to "economic behaviour", Table 14
** sum of first 2 columns. Totals subject to rounding error

These results can be usefully compared with those in Stock and Watson (2003b) who focus on the volatility of output growth in the US and Euro area. They attribute 26% of the post-1984 fall in output volatility in the Euro area to improved monetary policy, which they equate solely with changed interest rate behaviour. At most, 7% of the reduction in US growth volatility is similarly attributed; indeed, they find instances where the shift in U.S. monetary policy *increased* growth volatility by up to 10%. The average of their three estimates suggests that monetary policy *raised* US growth volatility by 2%.

These rival estimates are affected by the nature of the counterfactuals considered in the calculations. Stock and Watson calculate the impact on growth variance of their pre-1979 interest rate equation given the shocks and other attributes of the later period. This restricted comparison leaves out of account other valid backward-forward comparisons. For example, the authors do not ask by how much period 1's growth variance might have been reduced by the improved monetary policy of period 2 or what the effect would have been with different characterisations of inflation propagation.

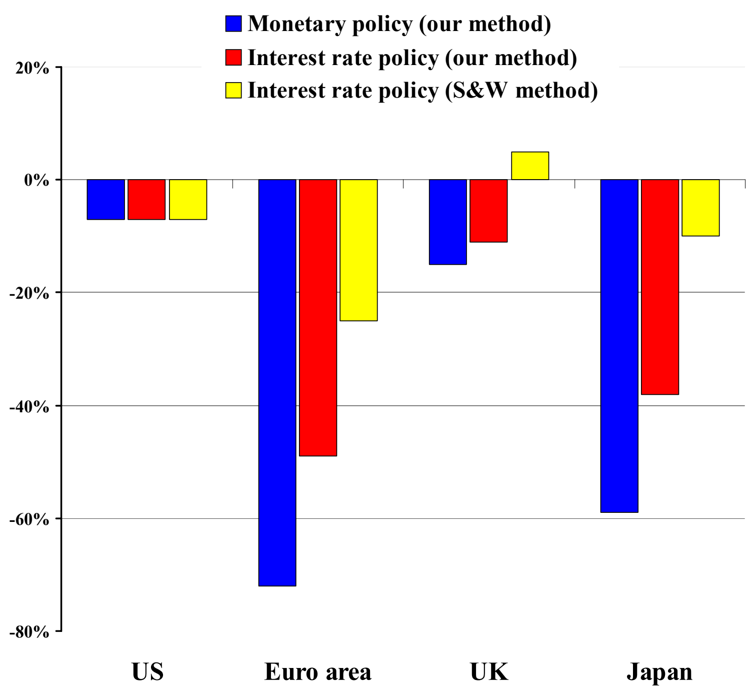
Table 16: Fall in growth variance, % contribution

%	--------------- Shocks ---------------		---------- Interest rate policy ----------	
Calculation method	**This study**	**Stock and Watson**	**This study**	**Stock and Watson**
United States	-100	-101	-7	-7
Euro area	-21	-21	-49	-25
United Kingdom	-107	-101	-11	5
Japan	-21	-28	-38	-10

Source: Stock and Watson (2003b); authors' calculations. Calculation method: This study – as described in text; Stock and Watson – as in Stock and Watson (2003b) but using our simulation results. The equivalent figures (with appropriate sign convention) in Stock and Watson (2003b) are for US growth: between -82% and -140% (shocks) and between -7% and +10% (interest rate policy); for Euro area growth: -26% (interest rate policy)

To assess the impact of methodology, Table 16 compares the effect of applying Stock and Watson's method to our simulation results with our estimates based on our more exhaustive assessment of counterfactuals. The table shows that methodology does not materially affect the assessment of the role played by shocks but does affect the assessment of interest rate policy. Emulating Stock and Watson's method, our simulations produce estimates for the impact of interest rate policy in the US and Euro area that are close to theirs. But in every case except the US, our exhaustive method produces estimates of the role played by interest rate policy that are greater than implied by the Stock and Watson method. Adding in the impact of changed inflation behaviour further increases the divergence between the two approaches, as Figure 1 illustrates.

Figure 1: Monetary policy growth variance impact



The role of shocks

Despite the importance of policy seen in these results, the counterfactual exercises still identify shocks as a key source of lower growth variability in the US and UK and of lower inflation variability in the UK and Japan. We need to dig deeper.

As a first step, it is useful to know whether the reduction in volatility arose from direct shocks either to output or inflation or indirectly from other types of shock. For example, a reduction in inflation variability might arise from changes in output shocks rather than from shocks directly affecting inflation. We distinguish between four types of direct shock: to output, to inflation, to short-term interest rates and to the budget-deficit-to-GDP ratio.

As Table 17 records for cases where shocks are key, the results are straightforward. The reduction in growth volatility in the US and UK is mainly attributable to changes in direct shocks to output. The reduction in inflation volatility in the UK and Japan is mainly attributable to changes in direct shocks to inflation, though in Japan output shocks were also quite important. Some would draw the implication that instability could easily return with another bout of misfortune that caused large output and inflation shocks. But this would be a non sequitur. What is required is a theory to explain the shocks.

Table 17: Stability contributors – types of shock

% of change in variance	-------------- Contribution of shocks directly affecting: --------------				
	Output	Inflation rate	Interest rate	Budget deficit	All*
Growth					
United States	-85	-3	-7	-5	-100
United Kingdom	-89	9	-5	-22	-107
Inflation					
United Kingdom	-9	-79	-3	0	-92
Japan	-24	-39	-2	1	-63

Source: authors' calculations * as in final column, Table 14, subject to rounding error. Budget deficit shocks derived from SURE regressions relating the budget-deficit-to-GDP ratio to the output gap and to the lagged ratio with allowance for intercept and slope shifts and shock dummies – see appendix. As in other tables, shocks are adjusted to include the effect of shock dummy variables.

This is easier said than done. Shocks are, by definition, the things that the economic model in question does not explain. In their investigations, Stock and Watson (2002) found that identifiable shocks accounted for rather little of the observed decline in the variability of US growth. Oil price shocks made "a negligible contribution" or, on some measures, went the "wrong way"; productivity and commodity price shocks made a modest contribution "in the neighbourhood of 15%". Much the greater part of the decline in US volatility was due to unknown shocks. Other possibilities need consideration.

Ormerod (2002) suggests intriguingly that the long secular decline in US growth volatility might be due to a reduction in industrial concentration. If shocks to GDP are considered as a summation of shocks hitting individual enterprises, and the shocks are not highly correlated, the greater the number of enterprises, the smaller would be the variability of shocks to GDP. But whatever its merits as an explanation of the secular decline in US growth volatility, it seems unlikely that changes in industrial concentration can explain the fall in the variability of shocks since the 1970s and early-1980s. Limited and somewhat dated estimates of industrial concentration show that it has increased in US, UK and German manufacturing since the late-1960s (van Ark and Monnikhof (1996)).

The most obvious cause of the changed volatility of shocks is inflation. During the 1970s, expectations of inflation were probably highly volatile, subject to what the late Oxford economist John Flemming called "changes of gear" (Flemming (1976)). Rapid changes in inflation expectations would have added to the volatility of inflation itself. And jumps in inflation may well have caused real disruption, affecting households' and businesses' liquidity, cash flow and confidence. As Bernanke (2004) notes, such events would be registered as "shocks" in standard economic models. It is certainly the case that mainstream econometric models of the macro-economy generally broke down in the 1970s.

A counterargument would point to the importance of massive oil price hikes in 1973 and 1979. But the pricing decisions taken by OPEC, the oil producers' cartel, were partly dependent on their perceptions of oil importers' economic policies. Policies in the West that were perceived to accommodate inflation might well have encouraged a more aggressive OPEC stance. Barsky and Kilian (2001) argue convincingly that the oil price shocks were caused, in part, by excessive monetary expansion.

Such considerations help to explain the well-documented tendency for the variability of inflation to rise and fall with its level. Not surprisingly, we also find that the variability of *shocks* to inflation is geared to the average inflation rate. According to a simple regression that pools information on the four regions used in this study, a 1-percentage point increase in the rate of inflation has been associated with an increase of a third in the standard deviation of inflation shocks, an estimate not unlike one used by Bean (1998) in his account of UK inflation.

In addition, we find that the variability of output shocks is significantly and systematically related to the average inflation rate but only episodically related to oil prices. Historically, a 1-percentage point change in the inflation rate has been associated with a change of about a tenth in the standard deviation of output shocks (see the appendix for details). Although only suggestive, these results are comparable to those offered by Barrell and Gottschalk (2004) and Blanchard and Simon (2001) who find a relationship between the variability of growth and of inflation[10]. The simulations of Orphanides and Williams (2004) also provide supporting evidence. They find that the rise in US inflation and in inflation persistence in the 1970s, the result of monetary policy errors and changes of gear in the formation of inflation expectations, raised the volatility of both inflation and unemployment.

Taking our coefficient, Table 18 considers the possible contribution of the fall in inflation to the change in the volatility of output shocks between the turbulent decade to 1983 and the benign decade ending in 2003. For the US and UK, the calculations suggest that the decline in inflation accounts for all the fall in output shock variability. In Japan, the comparable figure is over 70%. In the Euro area, the fall in output shock volatility is much less than would be expected as a result of inflation's fall, suggesting that other developments (monetary union?) may have been a source of countervailing disturbance.

Table 18: Accounting for output shock variability

Output shock standard deviation	Change 1974-1983 to 1994-2003	Inflation contribution % of variance change
United States	-0.5	-99
Euro area	-0.3	-240
United Kingdom	-1.1	-101
Japan	-0.8	-72

Source: authors' calculations "Output" refers to the output gap

These findings add weight to the view that the 1970s period was anomalous and a creation of unstable and high inflation. If so, there are two important implications.

First, the counterfactual exercises, while useful as a first pass, are likely to overstate the role played by shocks and understate the role played by monetary policy. The defeat of inflation appears to have reduced the inflation shocks that predominantly account for the decline in inflation volatility in the UK and Japan. In addition, lower inflation may well have fostered smaller output shocks that account for most of the decline in US and UK growth volatility.

The second implication concerns the future. If policy makers continue to target low inflation, and do so credibly, there is probably much less reason to fear a return of 1970s style output and inflation shocks.

Volatility scenarios

On this basis, we construct a base case scenario of economic volatility over the next decade using the experience of the last 20 years as a guide. The range of shocks during this period is probably wide and varied enough to represent the uncertainties of a future that today is at risk from global imbalances.

To build the scenario, we pepper our low-inflation-era depiction of economies with 150 sets of pretend shocks to output, inflation, interest rates and the budget deficit. On average, these shocks have the same characteristics as those of the last two decades – the same volatility and the same correlation, both within and across regions. Based on our earlier review, the process of globalisation is assumed not materially to affect these inter-relationships. We calculate the volatility of growth and inflation of the major economies separately and treating them as a single (G10) economy. The final result, an average of the 150 simulations, is also affected by current and assumed long-run economic conditions[11].

[10] Barrel and Gottschalk (2004) also emphasise the stabilising role of greater openness to trade and finance, though many studies find either contrary results or no stable relationship with openness (see, for example, Buch, Döpke and Pierdzioch (2002a); Karras and Song (1996); Kose, Prasad and Terrones (2003); Razin and Rose (1994)).

[11] Intercept adjustments are made to produce results that on average accord with consensus forecasts for 2004 and consensus long-run projections for growth, inflation and budget deficits.

Table 19: Past and projected volatility – base case

%	1954-1973	1994-2003	2004-2013
Growth			
United States	2.5	1.2	1.8
Euro area	1.1	0.9	1.2
UK	1.8	0.8	1.4
Japan	2.4	1.5	1.5
G10	1.4	0.8	1.1
Inflation			
United States	1.6	0.4	0.6
Euro area	1.7	0.6	0.6
UK	2.4	0.7	1.1
Japan	2.7	0.9	1.0
G10	1.5	0.3	0.5

Source: authors' calculations   Standard deviations of real GDP growth and inflation

Table 19 reports the projected volatilities in the demanding context of previous periods of relative tranquillity: the two decades of the "Golden Age" up to 1973 and the "nice" decade ending in 2003.

Compared with the last decade, the projections show:

- a modest (though not statistically significant) increase in growth volatility in the US, Euro area and UK, with no change in Japan[12];
- small increases in the volatility of inflation in the US and UK and little or no change in the Euro area or Japan.

These projections support King's (2003) contention that the last decade was an exceptional period, unlikely to be repeated. But in a wider context, the results show most economies enjoying an unusual degree of macroeconomic stability, at least equal to that experienced in the post-war Golden Age of the 1950s and 1960s. Prospective G10 growth and inflation volatility is lower.

As before, any reading of volatility has to take into account the economy's trend rate of growth. At first sight, Table 19 suggests that the Euro area would remain the most stable of the major economic regions. But this would amount to stability around a relatively low trend rate of growth. Conversely, the higher growth volatility in the US occurs against a background of a faster trend rate of growth.

A more revealing comparison, and one that better reflects changes in economic welfare (see, Galí, Gertler and López-Salido (2003)), comes from an examination of the likelihood of severe recession – defined, as in Table 4, as a zero change or fall in annual GDP. Since projected volatility is largely insensitive to changes in trend growth, the chance of severe recession rises if trend growth falls.

Table 20 shows the frequency of severe recession granted our base case assumptions for trend growth. Broadly in line with consensus thinking, these envisage annual trend growth of 3.2% in the US, 2% in the Euro area, 2.5% in the UK and 1.5% in Japan. Actual average rates of growth depend on the shocks and any catch-up from the early-2000s recession. Growth in Japan, for example, averages 1.7% a year over the next decade. To test sensitivities, the table also reports the impact of assuming trend growth rates that are uniformly 0.5 percentage points lower than in the base case.

Table 20: Severe recession probabilities

%	Past	-------------------------- Projection --------------------------	
	1954-1973	base case	lower trend growth
United States	10	2.9	5.3
Euro area	0	3.8	8.2
UK	0	4.2	8.1
Japan	0	13.2	21.5
G10	0	0.7	2.4

Source: authors' calculations Frequency of occurrence of zero or negative GDP growth in any year.
Projections based on 150 replications

[12] Significance is judged on the basis of (wide) standard errors over the next decade. Output gap variability follows a similar pattern to that of growth except in the US case where projected variability shows no rise.

The results show that US severe recession risk over the next decade is rather lower, albeit insignificantly so, than that in the Euro area or the UK, notwithstanding the higher volatility of US growth. Compared with the Golden Age, US severe recession risk falls, even on weak trend growth assumptions. Prospective severe recession risk in Europe is a little higher than in the Golden Age.

With low trend growth but middling growth volatility, Japan is the most exposed to severe recession risk. The projections imply that Japan could expect to experience zero growth or a fall in GDP in 1 or 2 years over the next decade. The prospective risk is substantially higher than in Japan's Golden Age.

Despite Japan's problems, diversified regional experience means that the risk of severe recession in the G10 is less than 1% on base case trend growth assumptions and still less than 3% with lower trend growth, risks not substantially different from Golden Age experience.

Another aspect of stability is represented by the risk of encountering the lower bound – typically taken to be zero - for nominal short-term interest rates. If interest rates cannot fall below zero (as assumed in our simulations), output could become permanently and increasingly depressed in circumstances of severe price deflation that raised the real rate of interest.

The probabilities reported in Table 21, conditioned by current circumstances, are in line with other research findings for economies outside Japan (see, for example, the review in Yates (2002)). In the US and Europe, the likelihood of encountering the zero bound in the next decade is put in the range of 1%-10% granted normal nominal interest rates of between 2.5% and 4.7%. In our models, the normal interest rate is governed by the prospects for trend growth and average inflation. In Japan, where our base case presumes a normal nominal interest rate of only 1.5%, the probability of being at the zero bound is in excess of 30%. Were the normal nominal interest rate just 0.5%, the Japanese economy would be at the lower bound over half the time.

Table 21: Zero bound probability in next decade

%	Base case	Lower normal interest rate*
United States	2.3	2.9
Euro area	3.5	9.9
UK	1.0	2.9
Japan	32.1	55.1

Source: authors' calculations Frequency of occurrence of zero nominal interest rates in any year based on 150 replications. Base case steady-state nominal interest rates are: 4.7% (US), 3.5% (Euro area); 4.5% (UK); 1.5% (Japan). * 1 percentage point lower than in base case

Alternative scenarios

In general, the base case paints a fairly benign picture. It points to the continuation of historically low inflation volatility (albeit rising in the UK) and limited chance of severe recession outside Japan. Growth volatility rises in the US and UK but not to "turbulent" levels. We now consider the sensitivity of these results to alternate assumptions about policy rules and shock assumptions.

Tables 22 and 23 entertain three alternatives. First, given base case assumption about shocks, we envisage how outcomes might be affected by possible improvements in the conduct of monetary and fiscal policy. Although artificial, the amended policy rules may be taken to represent a shift towards more active demand management made possible in a low inflation environment[13].

The second and third alternative scenarios envisage different distributions of shocks and surprises. The first variant ("Shock90") uses only the last decade as a basis for the estimation of the distribution of shocks; the second variant ("Shock70") uses the experience of the turbulent 1970s and early-1980s.

The results for the "policy" scenario show only a very modest improvement on the base case, suggesting limited room for further macroeconomic policy gains if our simple models are any guide. The more significant changes arise from the different assumptions about shocks. The "Shock90" variant has little impact on economies except the UK. Lower volatility of shocks to UK output and inflation leads to greater stability and reduced risk of severe recession.

[13] In particular, we raise the coefficients on the output gap in the interest rate and budget deficit equations, a procedure that takes no account of the difficulty of real-time output gap estimation – see appendix for details.

This finding also helps corroborate King's (2003) contention that the past decade has been unusually benign, though our results point to the exceptionally low variance of UK shocks rather than to an effect arising, as King argues, from the time pattern of shocks.

Table 22: Alternative volatility scenarios

Standard deviation, 2004-2013, %	---------------------------- Scenarios ----------------------------			
	base case	policy	shock90	shock70
Growth				
United States	1.8	1.7	1.7	2.4
Euro area	1.2	1.2	1.2	1.5
United Kingdom	1.4	1.3	1.1	2.5
Japan	1.5	1.4	1.6	2.9
G10	1.1	1.1	1.0	1.5
Inflation				
United States	0.6	0.5	0.4	1.2
Euro area	0.6	0.6	0.5	0.7
United Kingdom	1.1	1.1	0.8	4.8
Japan	1.0	0.9	0.9	4.1
G10	0.5	0.4	0.3	0.9

Source: authors' calculations.

Table 23: Severe recession risk – alternative scenarios

%	---------------------------- Scenarios ----------------------------			
	base case	policy	shock90	shock70
United States	2.9	2.4	2.4	7.9
Euro area	3.8	3.1	3.7	6.7
United Kingdom	4.2	2.9	0.9	16.6
Japan	13.2	9.7	13.9	29.5
G10	0.7	0.7	0.6	5.4

Source: authors' calculations.

A return to 1970s style shocks would disturb all the major regions and materially increase severe recession risk. In such circumstances, prospective output and inflation volatilities would be generally lower than during the Great Inflation, thanks to better policy and lower inflation persistence. But this would be cold comfort. Compared with the last decade, output and inflation volatilities would be much higher in all regions except perhaps the Euro area, where shock variance increases least.

Conclusions

In drawing conclusions, it is worth stressing the simplicity of our models and approach. Further research could usefully test for robustness over alternative model specifications (see, for example, Stock and Watson (2003b)) and over alternative - non-normal - shock distribution assumptions. In particular, we would not seek to draw conclusions about policy optimisation from the current study; our assessment of the impact of alternative policy rules should be seen as no more than a simple sensitivity analysis of our baseline projections.

Will stability last? Our analysis suggests that the major economies, Japan excepted, could continue to enjoy an unusual degree of macroeconomic stability judged by post-war standards granted two conditions: first, the survival of the new monetary standard that credibly delivers low inflation and, second, the presence of shocks that are no more extreme than those seen over the last two decades.

Larger shocks are clearly possible, but we would argue that the varied and often unsettling events of this 20-year period are not an implausible basis for assessing the medium-term future (Martin (2004)). Although the next decade may not prove to be as "nice" as the last one, granted average luck and current institutions, a "not bad" outcome seems to us to be within the bounds of probability.

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Appendix

Inflation behaviour and policy preferences in a model of economic volatility

The following model illustrates the impact on the volatility of output and inflation of changes in economic structure and in policy preferences. Following Akerlof, Dickens and Perry (2000); Ball (1999); Bean (1998) and Svensson (1997), we consider an economy in which demand and inflation are described by the equations:

$$y = -\mu r_{-1} + \lambda y_{-1} + \eta \qquad (1)$$

$$\pi = \omega(\pi_{-1} + \alpha y_{-1}) + \varepsilon \qquad (2)$$

where: y is the output gap; r is the real interest rate; π is the inflation rate and η and ε are zero mean, independent white-noise disturbances with respective variances $\sigma_\eta^2, \sigma_\varepsilon^2$.

Equation (2) represents the aggregate outcome of decisions taken by two sets of firms, "A" and "B", with relative weights ω and (1-ω) respectively. "A" firms are "accelerationist" in their price setting:

$$\pi^A = \pi_{-1} + \alpha y_{-1}^A + \varepsilon^A \qquad (3)$$

while "B" firms are "flat-liners":

$$\pi^B = \pi^* + \varepsilon^B \qquad (4)$$

where π^* is a constant equal to the central bank's inflation target. Apart from their pricing decisions, the firms are identical so that $y^A = y^B = y$ and $\varepsilon^A = \varepsilon^B = \varepsilon$. For simplicity, we assume that $\pi^* = 0$.

The model has a recursive structure in which the interest rate affects output and output affects inflation each with a one period ("year") delay. Forced to take next year's inflation as given, the central bank must seek to affect inflation in *two* years time by setting the current real interest rate to alter *next year's expected* level of the output gap, Ey_{+1}.

The central bank's behaviour implies:

$$Ey_{+1} = -\rho E\pi_{+1} \qquad (5)$$

ρ being a positive parameter related to the authorities' trade-off between output and inflation volatilty.

Since expected inflation in two year's time is given by:

$$E\pi_{+2} = \omega(E\pi_{+1} + \alpha Ey_{+1}) \qquad (6)$$

it follows from the central bank's behaviour that:

$$E\pi_{+2} = \omega(1 - \rho\alpha)E\pi_{+1} \qquad (7)$$

If $\rho = \frac{1}{\alpha}$, then $E\pi_{+2} = 0$. In this case, the central bank pursues a pure (zero) inflation target. A case where $0 < \rho < \frac{1}{\alpha}$ corresponds to a generalised policy rule in which the inflation target is approached more gradually by a central bank that also has regard to the cost of output volatility.

The implied Taylor-like rule for the real interest rate can be derived by noting from equation (1) that:

$$Ey_{+1} = -\mu r + \lambda y \qquad (8)$$

and from equation (2):

$$E\pi_{+1} = \omega(\pi + \alpha y) \qquad (9)$$

Next year's expected output gap and inflation are linked through the central bank's behaviour described by equation (5). Substitution of equations (8) and (9) into (5) gives the following expression for the real interest rate:

$$r = \frac{(\lambda + \omega\rho\alpha)\mathrm{y} + \omega\rho\pi}{\mu} \qquad (10)$$

After substituting equation (10) into equation (1), the economy can be described in matrix notation:

$$\mathrm{X} = \mathrm{BX}_{-1} + \mathrm{F} \qquad (11)$$

where: $\mathrm{X} = \begin{bmatrix} \mathrm{y} \\ \pi \end{bmatrix}$, $\mathrm{B} = \omega \begin{bmatrix} -\rho\alpha & -\rho \\ \alpha & 1 \end{bmatrix}$, $\mathrm{F} = \begin{bmatrix} \eta \\ \varepsilon \end{bmatrix}$.

Using the standard result that:

$$\mathrm{Vec}[\mathrm{Var}(\mathrm{X})] = [\mathrm{I} - \mathrm{B} \otimes \mathrm{B}]^{-1} \mathrm{Vec}[\mathrm{Var}(\mathrm{F})]$$

where ⊗ denotes the Kronecker product, it follows, assuming zero correlation between the demand and supply disturbances, that the output gap and inflation unconditional variances are described by:

$$\mathrm{var(y)} = \frac{\rho^2\left(\alpha^2\sigma_\eta^2 + \sigma_\varepsilon^2\right)}{\rho\alpha(2 - \rho\alpha) - 1 + 1/\omega^2} + \sigma_\eta^2 \qquad (12)$$

and

$$\mathrm{var}(\pi) = \frac{\alpha^2\sigma_\eta^2 + \sigma_\varepsilon^2}{\rho\alpha(2 - \rho\alpha) - 1 + 1/\omega^2} + \sigma_\varepsilon^2 \qquad (13)$$

The model has several noteworthy features:

- Granted that monetary policy affects inflation only by affecting demand, it follows that developments in output and inflation are independent of the parameters describing the aggregate demand relationship: μ and λ. These parameters influence the interest rate rule.
- The volatility of output and inflation and their co-movement are determined solely by the characteristics of the supply curve (equation (2)) and by policy preferences (equation (5)).

The impact of a fall in inflation persistence combined with a flattening of the short-run Phillips curve, features of the empirical evidence, can be found by differentiating equations (12) and (13) with respect to ω and reversing the sign.

The effect on the variance of the output gap is given by:

$$-\frac{2\omega\rho^2(\alpha^2\sigma_\eta^2 + \sigma_\varepsilon^2)}{(\omega^2\rho^2\alpha^2 - 2\omega^2\rho\alpha + \omega^2 - 1)^2} \qquad (14)$$

and on the variance of inflation by:

$$-\frac{2\omega(\alpha^2\sigma_\eta^2 + \sigma_\varepsilon^2)}{(\omega^2\rho^2\alpha^2 - 2\omega^2\rho\alpha + \omega^2 - 1)^2} \qquad (15)$$

- in both cases negative. This result could be taken as indicative of the impact of a more credible (zero) inflation target that reduces the positive feedback embedded in the system of equations (1) and (2) by increasing the preponderance of flat-liner-pricing firms.

The impact of more inflation-averse policy preferences can be found by differentiating equations (12) and (13) with respect to ρ. The effect on the variance of the output gap is given by:

$$\frac{2\omega^2\rho(1+\omega^2\{\rho\alpha-1\})(\alpha^2\sigma_\eta^2+\sigma_\varepsilon^2)}{(\omega^2\rho^2\alpha^2-2\omega^2\rho\alpha+\omega^2-1)^2} \qquad (16)$$

and on the variance of inflation by:

$$\frac{2\omega^4\alpha(\rho\alpha-1)(\alpha^2\sigma_\eta^2+\sigma_\varepsilon^2)}{(\omega^2\rho^2\alpha^2-2\omega^2\rho\alpha+\omega^2-1)^2} \qquad (17)$$

The variance of output increases while inflation variance falls given a general policy rule with $\rho < \frac{1}{\alpha}$.

The impact of a change in the slope of the short-run Phillips curve can be examined by differentiating equations (12) and (13) with respect to α. The effect on the variance of the output gap is given by:

$$\frac{2\omega^2\rho^2\left\{\alpha(1+\omega^2\{\rho\alpha-1\})\sigma_\eta^2+\omega^2\rho(\rho\alpha-1)\sigma_\varepsilon^2\right\}}{(\omega^2\rho^2\alpha^2-2\omega^2\rho\alpha+\omega^2-1)^2} \qquad (18)$$

and on the variance of inflation by:

$$\frac{2\omega^2\left\{\alpha(1+\omega^2\{\rho\alpha-1\})\sigma_\eta^2+\omega^2\rho(\rho\alpha-1)\sigma_\varepsilon^2\right\}}{(\omega^2\rho^2\alpha^2-2\omega^2\rho\alpha+\omega^2-1)^2} \qquad (19)$$

Although the variances of output and inflation move in the same direction, the impact of changes in inflation's sensitivity to output is generally ambiguous. Only in the case where the central bank pursues a pure inflation target, $\rho = \frac{1}{\alpha}$, are expressions (18) and (19) unambiguously positive. In this case, a flatter Phillips curve would lead to falls in output and inflation variances that depend on the supply curve and the scale of demand shocks.

With less extreme policy preferences, however, the direction of impact is ambiguous, the result depending on the relative importance of supply and demand shocks. If supply shocks predominate, output and inflation variances could increase as inflation's sensitivity to output falls.

Table A1 summarises the impact of model parameter shifts on macroeconomic stability. Since all these parameters may have changed over time and have offsetting effects, the net impact is unclear. It should be stressed that the model's results refer to asymptotic variances, which are unlikely to be a foolproof guide to developments over limited historical time spans.

Table A1: Theoretical impact of regime changes

Nature of change	**-------------------- volatility of**	**--------------------**
	output	**Inflation**
More credible inflation target	down	Down
Increase in policy-makers' inflation aversion	up	Down
Fall in inflation's output sensitivity	?	?

Source: authors' analysis

Accounting for volatility

Our decomposition of variance differences is based on the counterfactuals described in Table 13 in the main text. To make explicit the nature of this decomposition, first consider the autoregressive scheme:

$$Z_t = CZ_{t-1} + e_t$$

where Z_t and the residuals e_t are vectors and C is a coefficient matrix that defines economic behaviour - the propagation mechanism. Expanding this equation yields:

$$Z_t = C^t Z_0 + \sum_{j=1}^{j=t} C^{t-j} e_j$$

Suppose that the initial vector Z_0 is modified by an amount ΔZ_0, the shock vector by amounts Δe_j and the coefficient matrix C by an amount ΔC.

Define for the counterfactual sets in Table 13 the following new values of Z_t:

Set A1: $Z_t^{ISP} = (C+\Delta C)^t (Z_0 + \Delta Z_0) + \sum_{j=1}^{j=t} (C+\Delta C)^{t-j} (e_j + \Delta e_j)$ (Z_0, e_j and C modified)

Set A2: $Z_t^{IP} = (C+\Delta C)^t (Z_0 + \Delta Z_0) + \sum_{j=1}^{j=t} (C+\Delta C)^{t-j} e_j$ (Z_0 and C modified)

Set A3: $Z_t^{IS} = C^t (Z_0 + \Delta Z_0) + \sum_{j=1}^{j=t} C^{t-j} (e_j + \Delta e_j)$ (Z_0 and e_j modified)

Set A4: $Z_t^{I} = C^t (Z_0 + \Delta Z_0) + \sum_{j=1}^{j=t} C^{t-j} e_j$ (Z_0 modified)

Set A5: $Z_t = C^t Z_0 + \sum_{j=1}^{j=t} C^{t-j} e_j$ (No modifications)

Set A6: $Z_t^{S} = C^t Z_0 + \sum_{j=1}^{j=t} C^{t-j} (e_j + \Delta e_j)$ (e_j modified)

Set A7: $Z_t^{P} = (C+\Delta C)^t Z_0 + \sum_{j=1}^{j=t} (C+\Delta C)^{t-j} e_j$ (C modified)

Set A8: $Z_t^{SP} = (C+\Delta C)^t Z_0 + \sum_{j=1}^{j=t} (C+\Delta C)^{t-j} (e_j + \Delta e_j)$ (e_j and C modified)

These can be written in the form:

Set A1: $Z_t^{ISP} = Z_t + I_t + S_t + P_t + u_t$

Set A2: $Z_t^{IP} = Z_t + I_t + P_t + v_t$

Set A3: $Z_t^{IS} = Z_t + I_t + S_t$

Set A4: $Z_t^{I} = Z_t + I_t$

Set A5: Z_t

Set A6: $Z_t^{S} = Z_t + S_t$

Set A7: $Z_t^{P} = Z_t + P_t$

Set A8: $Z_t^{SP} = Z_t + S_t + P_t + w_t$

where: $I_t = C^t \Delta Z_0$; $S_t = \sum_{j=1}^{j=t} C^{t-j} \Delta e_j$; $P_t = \left[(C+\Delta C)^t - C^t\right] Z_0 + \sum_{j=1}^{j=t} \left[(C+\Delta C)^{t-j} - C^{t-j}\right] e_j$

$u_t = \left[(C+\Delta C)^t - C^t\right] \Delta Z_0 + \sum_{j=1}^{j=t} \left[(C+\Delta C)^{t-j} - C^{t-j}\right] \Delta e_j$; $v_t = \left[(C+\Delta C)^t - C^t\right] \Delta Z_0$

$$w_t = \sum_{j=1}^{j=t} \left[(C + \Delta C)^{t-j} - C^{t-j} \right] \Delta e_j$$

The terms I_t S_t and P_t are the changes in Z_t that arise when initial conditions, shocks and the propagation mechanism are modified in isolation from each other. The terms u_t, v_t, w_t consist of cross-products of powers of ΔC with ΔZ_0 or Δe_j. Such interaction terms arise when modifications to the propagation mechanism are combined with modifications to the initial conditions or shocks. In this case, the full effect is not a simple sum of parts. Note that there are no interaction terms involving cross-products between ΔZ_0 and Δe_j. Thus modifications to initial conditions and shocks are additive.

For each of the counterfactual sets, A1 to A8, define corresponding variances, *V*1 to *V*8:

Set A1: $V1 = Var(Z_t^{ISP})$

Set A2: $V2 = Var(Z_t^{IP})$

Set A3: $V3 = Var(Z_t^{IS})$

Set A4: $V4 = Var(Z_t^{I})$

Set A5: $V5 = Var(Z_t)$

Set A6: $V6 = Var(Z_t^{S})$

Set A7: $V7 = Var(Z_t^{P})$

Set A8: $V8 = Var(Z_t^{SP})$

The total change in the observed variance, *V*1-*V*5, can be decomposed as follows:

Initial conditions contribution:

$$\left[(V4 - V5) + 0.5\langle (V2 - V7) + (V3 - V6) \rangle + (V1 - V8) \right] / 3 = Var(I) + 2Cov(I,Z) + Cov(I,S) + Cov(I,P) + \tfrac{1}{3}(\phi + \theta - 2\varsigma)$$

Shocks contribution:

$$\left[(V6 - V5) + 0.5\langle (V8 - V7) + (V3 - V4) \rangle + (V1 - V2) \right] / 3 = Var(S) + 2Cov(S,Z) + Cov(I,S) + Cov(P,S) + \tfrac{1}{3}(\phi - 2\theta + \varsigma)$$

Economic behaviour (propagation mechanism) contribution:

$$\left[(V7 - V5) + 0.5\langle (V8 - V6) + (V2 - V4) \rangle + (V1 - V3) \right] / 3 = Var(P) + 2Cov(P,Z) + Cov(I,P) + Cov(P,S) + \tfrac{1}{3}(\phi + \theta + \varsigma)$$

where:

$$\phi = Var(u) + 2\left[Cov(u,Z) + Cov(u,I) + Cov(u,P) + Cov(u,S) \right]$$

$$\theta = \tfrac{1}{2}\left(Var(v) + 2\left[Cov(v,Z) + Cov(v,I) + Cov(v,P) \right] \right)$$

$$\varsigma = \tfrac{1}{2}\left(Var(w) + 2\left[Cov(w,Z) + Cov(w,P) + Cov(w,S) \right] \right)$$

Each of the contributions falls into two main parts: the first four terms that comprise a linear variance-covariance decomposition and a fifth term that splits the non-linear impact of changes in the propagation mechanism. It may be noted that in a linear case where this final term is zero ($u_t = v_t = w_t = 0$), the contribution formulae can be expressed more simply as follows:

Initial conditions contribution:

$$\left[(V4 - V5) + (V1 - V8) \right] / 2$$

Shocks contribution:

$$\left[(V6 - V5) + (V1 - V2) \right] / 2$$

Economic behaviour (propagation mechanism) contribution:

$$\left[(V7 - V5) + (V1 - V3) \right] / 2$$

Our procedure can easily be extended to decompose the change in volatility within each class of contributor. Details are available on request.

Four-region regressions

We consider a simple representation of each region (ignoring any intercepts):

$y_t = A(L)y_{t-1} - \alpha_1(i_{t-1} - \pi_{t-1} - g_{t-1}) + \alpha_2 \nabla b_{t-1} + e_{y,t} + dummies$	output gap
$\pi_t = B(L)\pi_{t-1} + \alpha_3 y_{t-1} + e_{\pi,t} + dummies$	inflation
$i_t = C(L)i_{t-1} + D(L)\pi_t + E(L)y_t + e_{i,t} + dummies$	nominal interest rate
$b_t = F(L)b_{t-1} - G(L)y_t + e_{b,t} + dummies$	budget deficit

where: y is the output gap; π is inflation; *i* is the nominal (three-month) interest rate; *g* is the trend rate of growth; *b* is the ratio to GDP of the general government financial deficit; *A(L)-G(L)* are lag polynomials, α_1 to α_3 are positive coefficients; $e_{y,t}$ to $e_{b,t}$ are disturbances; ∇ is the one-year change.

Apart from the inclusion of a fiscal policy variable, the equations define a fairly standard backward-looking model of the type much used in policy-rule assessment (see, for example, Rudebusch and Svensson (1999)). Although lacking explicit open economy features, the model parameters and shocks can be broadly interpreted to reflect the effects of the exchange rate and of foreign output and prices (see, for example, Nelson and Nikolov (2002)). The results in Coenen and Wieland (2002) also suggest that the simulation properties of explicit open-economy models may not differ greatly from those of closed-economy models at this high level of abstraction.

Parameter constancy is assumed in the case of the output gap equation but the parameters of the inflation and policy equations are allowed to change between the high-inflation period (1968-1983) and the low-inflation period (1984-2003). Save for the nominal interest rate equation, each equation type is treated as a seemingly unrelated regression equation model across the four regions. In all regressions, coefficients are generally well determined, correctly signed and of a size that accords with existing evidence. The regressions fit acceptably and pass standard tests, albeit with limited degrees of freedom and after allowance for shock dummies of the 0, 1 or 1,-1 kind. The shocks in our simulations comprise the regressions' residuals and the impact of shock dummies. Table 10 in the main text summarises the characteristics of the inflation equations; other equation coefficients are provided in the following tables. Further details are available on request.

Table A2: Output gap equation coefficients

	---------- output gap ----------		real interest rate	budget deficit change*
lag in years	**1**	**2**	**1**	**1**
United States	0.90	-0.53	-0.21	0.28
Euro area	1.10	-0.42	-0.16	0.28
United Kingdom	1.35	-0.73	-0.12	0.28
Japan	1.40	-0.64	-0.19	0.28

Source: authors' calculations. SURE estimates, 1968 to 2003. Shock dummies in 1972 (Japan), 1974 (US, UK, Japan) and 1980 (UK). * estimated with equality restriction (Wald statistic 0.6)

Table A3: Short-term nominal interest rate equation coefficients

	interest rate	-------- inflation rate --------		-------- output gap --------	
lag in years	**1**	**0**	**1**	**0**	**1**
High inflation					
United States	-	0.44	-	-	0.37
Euro area	-	0.62	-	0.66	-
United Kingdom	-	0.21	0.16	0.73	-
Japan	-	0.37	-	-	0.22
Low inflation					
United States	0.34	1.01	-	0.74	-0.54
Euro area	-	0.74	0.89	0.53	-
United Kingdom	-	0.55	0.64	0.44	-
Japan	-	0.47	0.62	0.13	-

Source: authors' calculations, OLS estimates, pass Wu-Hausman test. Japan low-inflation regression estimated 1984-2000. High-inflation regressions include a "Volcker" dummy; low-inflation regressions include intercept shifts. Shock dummies in US (1992, 2002/03); Euro area (1972/73, 2002/03); Japan (1972/73, 1975).

Table A4: Budget deficit ratio equation coefficients

lag in years	change in output gap 0	output gap 0	budget deficit 1
High inflation			
United States	-	-0.51	-
Euro area	-0.84	-0.51	-
United Kingdom	-0.14	-	-
Japan	-	-0.11	0.73
Low inflation			
United States	-	-0.30	0.55
Euro area	-	-0.12	0.53
United Kingdom	-	-0.48	0.52
Japan	-	-0.18	0.59

Source: authors' calculations, SURE estimates, pass Wu-Hausman test. Regressions include intercept shifts. Shock dummies in US (2002/03); UK (1968, 1970, 1972, 1975/76, 1984/85, 1998/2000); Japan (1977, 1983)

In the stochastic projections, we consider amended policy rules as shown in Table A5.

Table A5: Amended policy rules

	------ inflation rate ------		------ output gap ------		budget deficit
lag in years	**0**	**1**	**0**	**1**	**1**
interest rate rule (all)	0.5	1.0	1.5	-1	0
budget deficit rule:					
US, Euro area	0	0	-0.5	0.5	0.5
UK, Japan	0	0	-1.0	1.0	0.5

Source: authors' analysis

Panel regressions of output shock variability

Table A6 reports simple panel regressions that relate the 5-year and 10-year (non-overlapping) trailing variance of output gap shocks to the variance of inflation shocks, the average inflation rate, the variance and level of real oil prices and a fixed effect for each country. Our preference for the use of non-overlapping periods severely reduces degrees of freedom in the 10-year period regressions, which are based on only 12 observations. The 5-year period regressions use 28 observations.

The results suggest that oil prices were not a predominant source of output shock variability. In the 5-year trailing variance regressions, the variance and level of real oil prices are individually and jointly (F =0.2) insignificant. However, the sample is affected by the extreme events in Japan in the mid-1970s that were evidently related to the oil price shock. A dummy variable returns a coefficient of 4.1.

Excluding oil price terms but retaining the 1970s Japanese dummy variable, regression (2) produces coefficients on inflation shock variance and on the inflation average that are of the expected sign, though neither is statistically significant. Significance is affected by the high collinearity of these variables, however. The results suggest the inflation variance regressor may be dropped while retaining the term in the inflation average. According to regression (3), two-thirds of the variation over time and economy in the 5-year trailing output gap shock variance can be explained by inflation.

A repeat of the same regression but with 10-year trailing variances (and very limited degrees of freedom) produces an almost identical and statistically significant coefficient (regression (4)). Using the standard deviation instead of the variance of output gap shocks as the dependent variable gives a coefficient on average inflation of 0.09 (t-statistic of 6.0).

Table A6: Output shock variance panel regressions 1969-2003, US, Euro area, UK and Japan

Trailing measure	Eq. no.	Dependent variable: variance of output gap shocks	Regressors: variance of inf. shocks	Regressors: inflation average	Regressors: real oil price variance	Regressors: real oil price average	Regression statistics: R-bar squared	Regression statistics: Standard error
5-year	**1**	Coeff	0.03	0.21	-0.00	-0.01	0.66	1.1
		t-value	1.2	2.0	-0.1	-0.4		
	2	coeff	0.04	0.19	-	-	0.69	1.1
		t-value	1.3	2.0				
	3	coeff	-	0.29	-	-	0.68	1.1
		t-value		4.3				
10-year								
	4	coeff	-	0.27	-	-	0.75	0.6
		t-value		5.5				

Source: authors' calculations Regressions use non-overlapping periods of 5-year (1969-2003) and 10-year (1974-2003) trailing variances of real oil prices and of shocks to output gaps and inflation. Inflation and real oil price means are calculated over the same periods. Regression sets include country fixed effect dummies. 5-year regressions use a zero-one dummy that excludes observations on Japan in the 1974 to 1978 period.

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