Financial market volatility and the worldwide fall in inflation

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Introduction

Financial market volatility is a topic of much contemporary interest. One reason for this interest is the worldwide move to financial deregulation in the 1980s and the associated rise in gross flows in the world's financial markets. Together, these imply a larger role for financial markets in the behaviour of the wider economy.

Interest in financial market volatility has also been heightened, however, because from time to time asset markets behave in ways that most people find inexplicable. The signal recent example is the 1987 stock market crash when, despite the absence of any obvious news, the Dow Jones Industrial Average fell by 22% on 19th October 1987, triggering stock market crashes around the world.

Of course if everyone believed in the efficient markets hypothesis, financial market volatility would not be very interesting. If we were confident that asset prices efficiently incorporated all public information about economic fundamentals, then financial market volatility would be for good reason and should not be a cause for concern. In this case, volatile asset prices would simply reflect volatile economic fundamentals.

This paper is concerned with the relationship between asset price volatility and the volatility of a key economic fundamental: inflation. The focus is on bond and foreign exchange markets and on the changes in volatility in these markets that occurred as inflation around the world fell and became less variable.

Economic theory implies that a decline in the volatility of a country's inflation rate should lead, other things equal, to a decline in the volatility of its bond yields. Similarly, a fall in the volatility of the inflation differential between countries should lead to a fall in the volatility of their bilateral exchange rates. In this paper, we use data on inflation, bond yields and exchange rates for OECD countries over the past two decades to test these theoretical predictions.

We find some empirical evidence that cross-country differences in inflation volatility help to explain cross-country differences in the volatility of bond yields. This evidence is most compelling when countries with very volatile inflation rates are included in the sample. We also find evidence that the widespread fall in inflation volatility in the late 1980s and 1990s has been responsible for a fall in bond yield volatility, although the fall in the volatility of bond yields has been less marked than the fall in inflation volatility.

By contrast, for OECD countries with moderate inflation rates, there is little evidence that the volatility of inflation differentials helps to explain exchange rate volatility. The large fall in the volatility of the inflation differentials between many pairs of countries in the 1990s has been associated with little, if any, systematic fall in the volatility of their bilateral exchange rates.

The rest of the paper is divided into two sections. The next section marshals the empirical evidence about inflation volatility and bond yield volatility on the one hand, and inflation differential volatility and exchange rate volatility on the other. The final section broadens the focus of the paper to

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consider the wider economic debate about financial market volatility, and discusses why we find different results in the bond and foreign exchange markets.

1. Financial market volatility - some facts

1.1 The bond market

We set the scene for a discussion of volatility by examining the relationship between the *level* of inflation and the *level* of nominal bond yields. The upper panel of Figure 1 shows 12-month-ended inflation rates for five OECD countries since the early 1970s. After the inflationary boom of the 1970s, inflation in all these countries declined in the 1980s and fell further into the 1990s. The lower panel of Figure 1 shows nominal long bond yields for these five countries over the same time period. Although the relationship between inflation and nominal bond yields is not always close, the figure suggests that nominal bond yields fell along with inflation over the course of the 1980s and into the 1990s.

As well as relying on visual evidence, we can also formalise the relationship between bond yields and inflation. For country j, we decompose the nominal bond yield, n_j, into the expected real yield, r_j, and expected inflation, π_j^e:[2]

$$n_j \equiv r_j + \pi_j^e. \tag{1}$$

It follows that the average nominal bond yield over a period of time, $\overline{n_j}$, is given by:

$$\overline{n_j} \equiv \overline{r_j} + \overline{\pi_j^e} \tag{2}$$

and the change in average nominal bond yields between two periods, $\Delta\overline{n_j}$, is given by:

$$\Delta\overline{n_j} \equiv \Delta\overline{r_j} + \Delta\overline{\pi_j^e}. \tag{3}$$

We now make two assumptions to enable equations (2) and (3) to be estimated. Firstly, we assume that capital mobility between countries is sufficiently high that average real interest rates are approximately equalised across countries. Then, $\overline{r_j} \approx \overline{r}$ is the average world real interest rate in the period and $\Delta\overline{r_j} \approx \Delta\overline{r}$ is the change in the average world real interest rate between two periods. Secondly, we assume that average past inflation is a good proxy for expected future inflation.[3] These two assumptions lead to the following regression equations:

$$\overline{n_j} = \alpha_1 + \beta_1\overline{\pi_j}$$

and

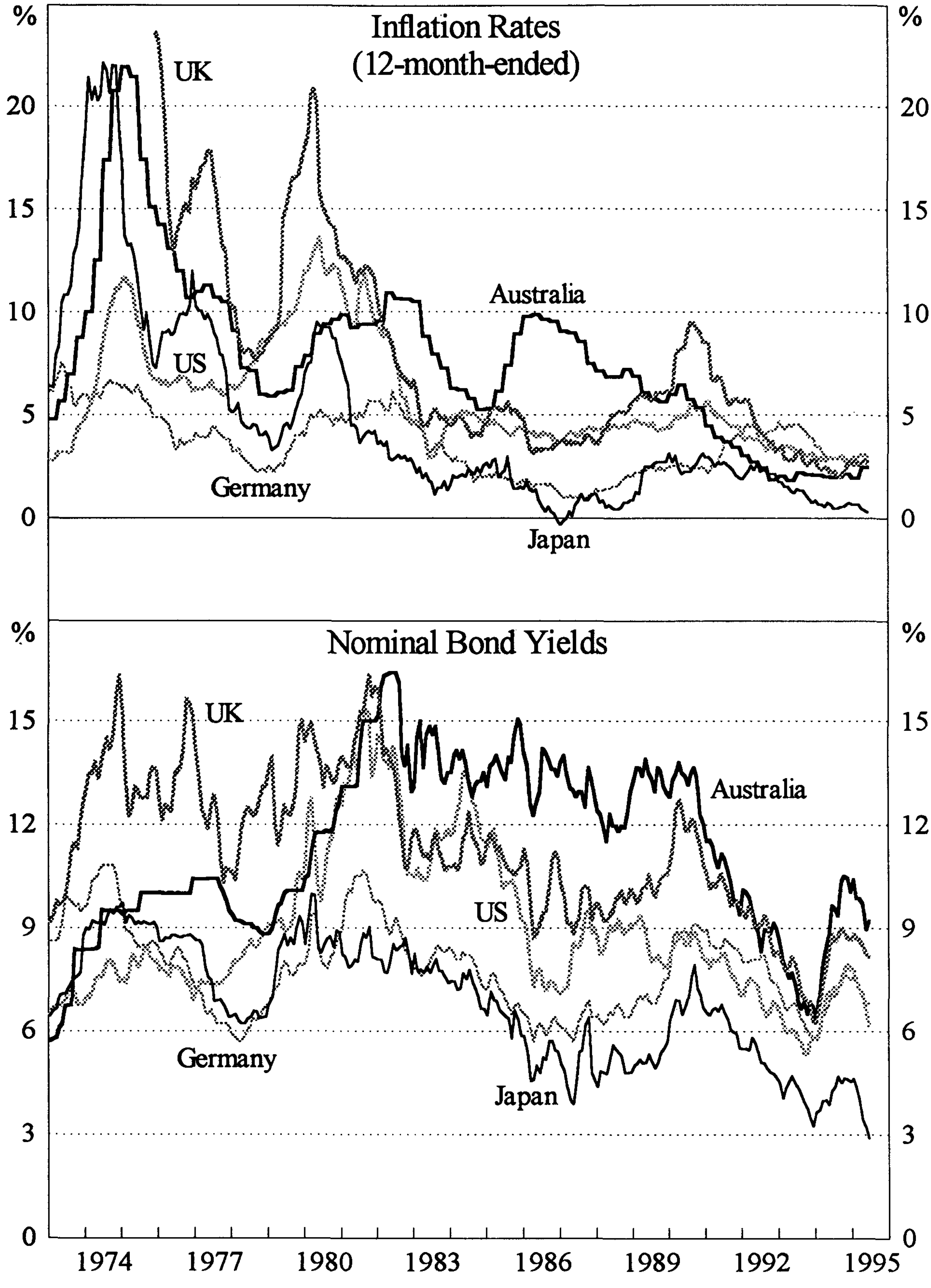
$$\Delta\overline{n_j} = \alpha_2 + \beta_2\Delta\overline{\pi_j}\ , \tag{4}$$

2 The equation can alternatively be thought of as defining the expected real interest rate, r_j, as $r_j \equiv n_j - \pi_j^e$.

3 This is quite a strong assumption, since at each point in time the relevant measure of expected inflation is expected inflation over the future life of the bond, which we proxy by actual inflation over the past 12 months. Clearly, the longer the period of time over which averaging is performed, the better this assumption should be.

Figure 1

Inflation rates and nominal bond yields for five OECD countries



where $\overline{\pi_j}$ and $\Delta\overline{\pi_j}$ are the average inflation rate in a period and the change in the average inflation rate between two periods.

We now divide our time period into three sub-periods of roughly equal length, 1973-80, 1981-87 and 1988-95, and expand our sample to fourteen OECD countries. Table 1 shows the result of estimating equation (4) for these fourteen countries, both in level form for the three time periods, and in difference form, between the first and second periods, and the second and third periods.

Table 1

Inflation and the level of nominal bond yields
(cross-country regressions, 14 countries)

	Levels $\overline{n}_j = \alpha + \beta\overline{\pi}_j$			**Differences** $\Delta\overline{n}_j = \alpha + \beta\Delta\overline{\pi}_j$		
	α	β	R^2	α	β	R^2
1973-80	5.85** (1.91)	0.41** (0.17)	0.33	-	-	-
1981-87	6.89** (0.91)	0.74** (0.12)	0.77	3.91** (1.01)	0.54** (0.23)	0.31
1988-95	4.26** (1.24)	1.40** (0.35)	0.57	- 1.69** (0.46)	0.39** (0.10)	0.55

Notes: 1. Standard errors are presented in parentheses below the coefficient estimates.
2. * and ** indicate that coefficients are significantly different from zero at 10% and 5%, respectively.
3. The regressions are over 14 countries: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Italy, Japan, New Zealand, Norway, the United Kingdom and the United States.
4. Data for the United Kingdom start in January 1976.

Over each seven-year period, the average inflation rate explains a sizable part of the cross-country variation in average nominal bond yields, and the change in average inflation from one period to the next explains much of the variation in the change in average bond yields. Furthermore, each estimate of β, the coefficient on average inflation or the change in average inflation, is of the expected positive sign and highly significant.

It also seems that nominal bonds yields have become more sensitive over time to the average level of inflation.[4] Be that as it may, the results overall are strongly supportive of the simple economic idea that the level of inflation is a key explanator of the level of nominal bond yields.

As a simple test of the robustness of these results, we repeat the regression analysis excluding from the sample two countries (Italy and New Zealand) with high inflation over much of the period. The results when these countries are excluded are reported in Table 2. There is minimal difference between the two tables, suggesting that the original results do not simply arise from the anomalous behaviour of a couple of high-inflation countries. Of course, none of this should come as a surprise. It is very much part of received economic wisdom that inflation is a key determinant of nominal bond yields.

We now turn to the issue of central interest. Does the simple and strong cross-country relationship between levels of inflation and nominal bond yields translate into a similar relationship between the variability, or volatility, of inflation and the volatility of bond yields?

4 The market for government long bonds in many countries was subject to substantial regulation in the 1970s and early 1980s, which may help to explain the weaker relationship between bond yields and inflation in the earlier periods. See Broker (1993) for further details.

Table 2

Inflation and the level of nominal bond yields
(cross-country regressions, 12 countries)

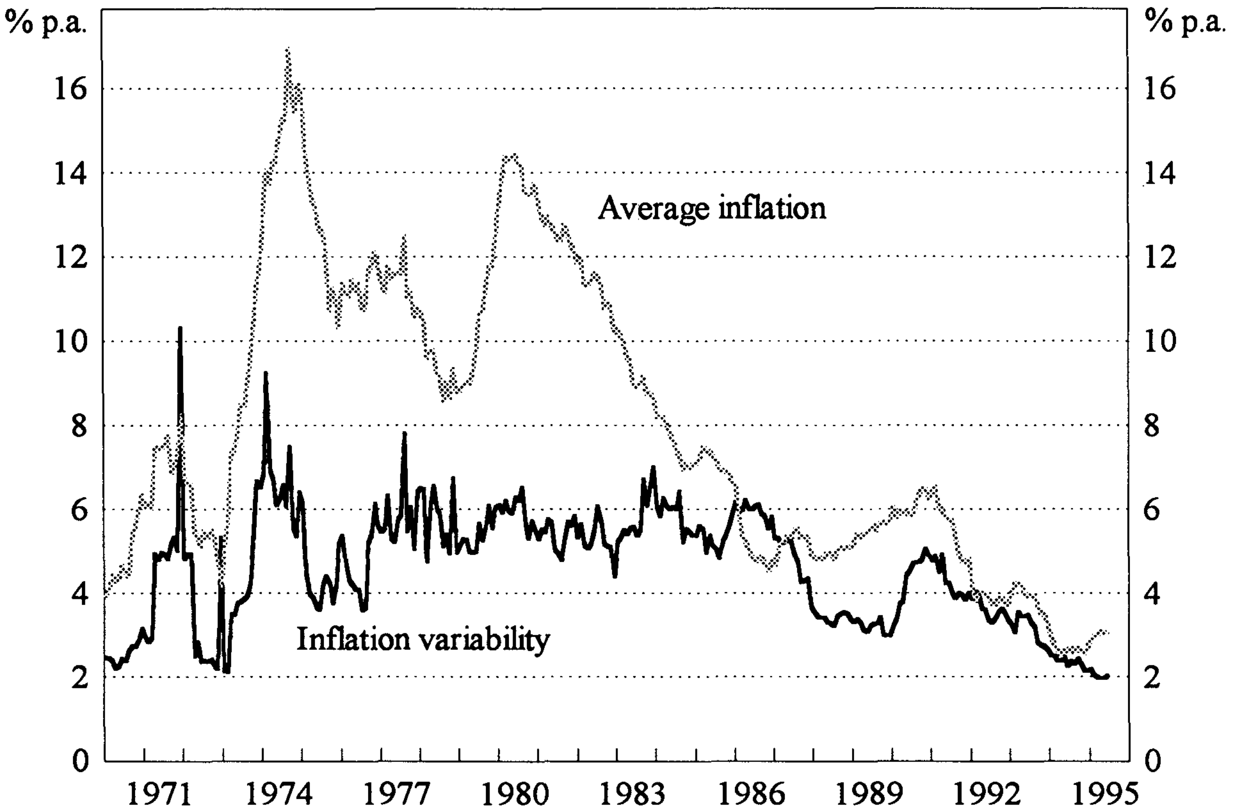
	Levels $\overline{n}_j = \alpha + \beta\overline{\pi}_j$			Differences $\Delta\overline{n}_j = \alpha + \beta\Delta\overline{\pi}_j$		
	α	β	R^2	α	β	R^2
1973-80	4.68* (2.13)	0.55** (0.21)	0.43	-	-	-
1981-87	5.77** (0.98)	0.94** (0.15)	0.81	3.47** (1.04)	0.53* (0.24)	0.33
1988-95	4.88** (1.31)	1.16** (0.38)	0.48	- 1.32** (0.48)	0.56** (0.13)	0.65

Notes: 1. Standard errors are presented in parentheses below the coefficient estimates.
2. * and ** indicate that coefficients are significantly different from zero at 10% and 5%, respectively.
3. The regressions are over 12 countries: Australia, Belgium, Canada, Denmark, Finland, France, Germany, Ireland, Japan, Norway, the United Kingdom and the United States.
4. Data for the United Kingdom start in January 1976.

Figure 2 shows average inflation in nineteen OECD countries as well as the standard deviation of inflation rates across these countries. Inflation in the 1990s is not only lower than in the previous two decades, it is also less variable, with the standard deviation of inflation across the nineteen countries lower in 1995 than at any time in the past quarter of a century.

Figure 2

Average inflation and inflation variability across the OECD



Note: The figure shows average 12-month-ended inflation and its standard deviation for 19 OECD countries. See the data appendix for further details.

Importantly, this lower variability of inflation in the 1990s is evident not only across countries at a point in time, as shown in Figure 2, but also within individual countries over time. Table 3 shows inflation volatility (measured by an average of the standard deviation of 12-month-ended inflation rates) in fourteen OECD countries over the periods 1973-87 and 1988-95. In all fourteen countries, inflation volatility is lower in the latter period than in the former.

Table 3

Volatility in inflation rates
(cross-country regressions, 14 countries)

	Inflation volatility		**Percentage change**	**Bond yield volatility**		**Percentage change**
	1974-87	**1988-95**		**1974-87**	**1988-95**	
Germany	0.39	0.28	- 28.6	0.44	0.37	- 17.7
United States	0.80	0.22	- 73.0	0.63	0.41	- 35.5
Australia	1.23	0.62	- 49.6	0.55	0.67	21.4
Japan	1.19	0.33	- 72.8	0.44	0.44	- 0.4
United Kingdom	1.50	0.58	- 61.3	0.86	0.53	- 38.1
Italy	2.66	1.19	- 55.2	0.81	0.70	- 14.1
France	1.09	0.30	- 72.7	0.59	0.45	- 23.3
Canada	0.72	0.61	- 15.5	0.60	0.45	- 25.1
Belgium	1.55	0.68	- 56.0	0.40	0.37	- 7.1
Denmark	1.84	0.62	- 66.5	1.03	0.58	- 43.4
Finland	1.07	0.60	- 44.1	0.43	0.76	75.3
Ireland	2.08	0.45	- 78.4	0.96	0.54	- 43.7
New Zealand	1.67	1.11	- 33.5	0.70	0.65	- 7.6
Norway	0.96	0.56	- 41.9	0.31	0.52	70.4

Note: Inflation volatility is the standard deviation, over the past 12 months, of monthly readings of the 12-month-ended inflation rate. Bond yield volatility is the standard deviation, over the past 12 months, of long-term bond yields (sampled monthly). For both measures, the first period starts in January 1974, except for the United Kingdom (November 1976).

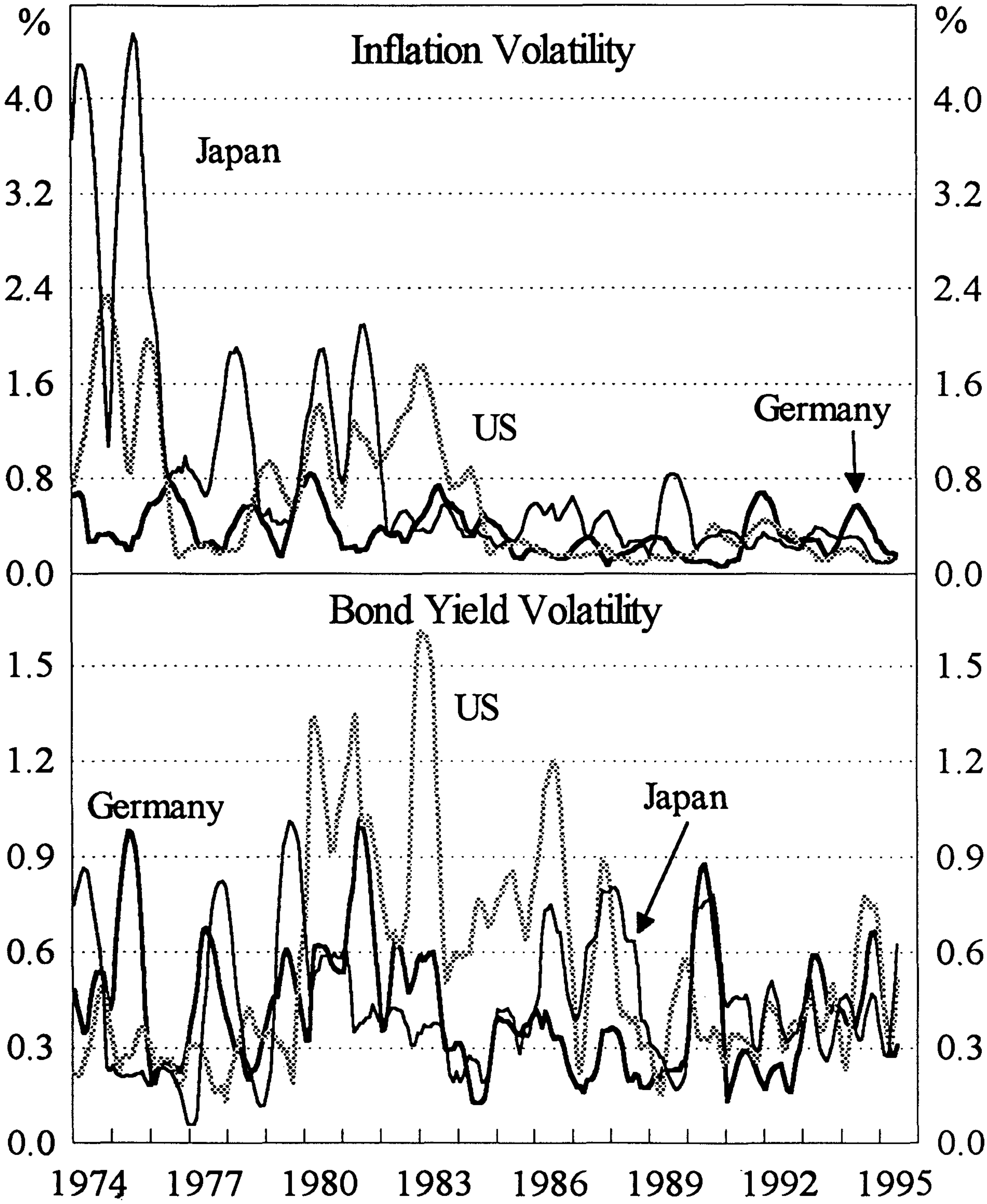
Has this lower inflation volatility translated into less volatility of bond yields? Table 3 also shows bond yield volatility (measured by an average of the standard deviation of monthly bond yields) for the same countries. For most countries, though not all, bond yield volatility has also declined over time. Somewhat disappointingly, the proportionate fall in bond yield volatility is usually much smaller than the fall in inflation volatility. In only a single country, Canada, was the percentage decline in bond yield volatility between the two periods larger than the decline in inflation volatility, while in three countries (Australia, Finland, and Norway) bond yield volatility was higher in the second period than in the first, despite falls in the volatility of inflation rates in each case greater than 40%.

Visual evidence is also provided by Figure 3, which shows a two-panel graph for the G-3 countries, with inflation volatility in the upper panel and bond yield volatility in the lower panel. Again, the fall in inflation volatility appears much more pronounced than the fall in the volatility of bond yields.

As before, we need not rely solely on visual evidence. We can also use the decomposition of the nominal bond yield into the expected real yield and expected inflation introduced earlier (equation (1)), to derive the relationship between the variance of nominal bond yields and the variances and covariance of the expected real yield and expected inflation:

Figure 3

Inflation and bond yield volatility for the G3 countries



Note: Inflation volatility is the standard deviation, over the past 12 months, of monthly readings of the 12-month-ended inflation rate. Bond yield volatility is the standard deviation, over the past 12 months, of long-term bond yields (sampled monthly).

$$Var_T(n_j) \equiv Var_T(r_j) + Var_T(\pi_j^e) + 2Cov_T(r_j, \pi_j^e), \quad (5)$$

where the notation $Var_T()$ means the variance evaluated over the past T months. As before, we take an average over time of equation (5) to give:

$$\overline{Var_T(n_j)} \equiv \overline{Var_T(r_j)} + \overline{Var_T(\pi_j^e)} + \overline{2Cov_T(r_j, \pi_j^e)}. \quad (6)$$

Similar to the assumptions made above, we assume that $\overline{Var_T(r_j)} = \overline{Var_T(r)}$ and that $\overline{Var_T(\pi_j^e)} = \gamma \overline{Var_T(\pi_j)}$; it is also assumed that the covariance term is constant.[5] This again leads to an equation we can estimate:

$$\overline{Var_T(n_j)} = \alpha + \beta \overline{Var_T(\pi_j)}. \quad (7)$$

Equation (7) has a very simple interpretation. The average variance, over time, of nominal bond yields should be positively related to the average variance of inflation rates. We divide the time period into three sub-periods, 1973-80, 1981-87 and 1988-95, and estimate equation (7) for a sample of fourteen OECD countries, both in levels for the three time periods, and in difference form between the first and second periods, and the second and third periods. Using two values for T, $T = 12$ months and $T = 84$ months (7 years), we report the results in Table 4.[6]

With only a single exception, the parameter β is estimated to be positive, as expected. That is, higher inflation volatility is correlated with higher volatility of bond yields. Furthermore, β is statistically significant in many cases. Judged by the regression R^2's of the equations, however, the explanatory power of equation (7) is usually much lower than the comparable cross-country relationship between the level of inflation and the level of nominal bond yields (equation 4).

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5 The assumption that $\overline{Var_T(\pi_j^e)} = \gamma \overline{Var_T(\pi_j)}$ can be justified in the simple case when inflation in each country follows a stationary AR(1) process, $\pi_t = \rho\pi_{t-1} + \varepsilon_t^j$, $\rho < 1$, where ε_t^j is the shock at time t specific to country j. For N-period bonds, assuming inflationary expectations over the life of the bond are rational, π_j^e at time-t is given by $\pi_j^e = E_t(\pi_{t+1} + \ldots + \pi_{t+N}) / N$. It is straightforward to show that $E_t\pi_{t+k} = \rho^k\pi_t$, and hence that $\pi_j^e = (\rho + \rho^2 + \ldots + \rho^N)\pi_t / N = \delta\pi_t$ where $\delta < 1$. Taking unconditional variances of both sides gives $Var(\pi_j^e) = \gamma Var(\pi_j)$ where $\gamma = \delta^2 < 1$ and $Var(\pi_j)$ is the unconditional variance of actual inflation in country j.

6 Using $T = 12$ months generates an average over the sample of the variance within a year, while $T = 84$ months generates the average variance over the sample. Both approaches generate a consistent estimate of the population variance for a stationary stochastic variable with no autocorrelation. $T = 12$ months implies that, each month, we calculate the 12-month-ended variances of n_j, the nominal bond rate (sampled monthly) and of π_j, which is itself the 12-month-ended inflation rate. These 12-month-ended variances are then averaged over the seven-year sample to generate $\overline{Var_{12}(n_j)}$ and $\overline{Var_{12}(\pi_j)}$. Alternatively, using $T = 84$ months (7 years) implies that the 84-month variances of nominal interest rates (sampled monthly), $Var_{84}(n_j)$, and of the 12-month-ended inflation rate, $Var_{84}(\pi_j)$, are calculated directly for each sample. The reason for calculating the variance of 12-month-ended inflation rates, rather than, for example, the variance of monthly inflation rates, is to deal with the possibility of seasonality in the inflation rate of some countries, which will raise the variance of monthly inflation rates even when underlying inflation is no more variable. Calculating the variance of 12-month-ended inflation rates eliminates this problem.

Table 4

The volatility of inflation and the volatility of nominal bond yields
(cross-country regressions, 14 countries)

	Levels $\overline{\sigma}_{12}^2(n_j)=\alpha+\beta\overline{\sigma}_{12}^2(\pi_j)$			Differences $\Delta\overline{\sigma}_{12}^2(n_j)=\alpha+\beta\Delta\overline{\sigma}_{12}^2(\pi_j)$		
	α	β	R^2	α	β	R^2
1973-80	0.24* (0.11)	0.052** (0.018)	0.41	-	-	-
1981-87	0.35** (0.15)	0.22** (0.067)	0.48	0.37** (0.12)	0.045* (0.025)	0.22
1988-95	0.29** (0.057)	0.13** (0.058)	0.31	- 0.070 (0.16)	0.26** (0.11)	0.34
	Levels $\sigma_{84}^2(n_j)=\alpha+\beta\sigma_{84}^2(\pi_j)$			**Differences** $\Delta\sigma_{84}^2(n_j)=\alpha+\beta\Delta\sigma_{84}^2(\pi_j)$		
	α	β	R^2	α	β	R^2
1973-80	1.88** (0.74)	0.026 (0.038)	0.04	-	-	-
1981-87	3.40* (1.69)	0.17 (0.098)	0.20	3.13** (1.08)	- 0.04 (0.088)	0.02
1988-95	0.83 (0.61)	0.51** (0.17)	0.43	- 1.37 (1.72)	0.19 (0.11)	0.20

Notes: 1. Standard errors are presented in parentheses below the coefficient estimates.
2. The 12-month-ended variances are averages for the three sub-periods. The first sub-period starts in January 1974, with the exception of the United Kingdom (November 1976).
3. 84-month variances are calculated over the periods: January 1974 to December 1980, July 1981 to June 1988, and July 1988 to June 1995. Data for the United Kingdom start in January 1976.
4. * and ** indicate that coefficients are significantly different from zero at 10% and 5%, respectively.
5. The regressions are over the same 14 countries as in Table 1.

We again test the robustness of the results by eliminating Italy and New Zealand from the sample and repeating the regressions. The results are reported in Table 5. In contrast to the earlier case, leaving out these two countries does make a substantial difference to the results. Although the estimates of β continue to be positive in most cases, they are much less statistically significant. Furthermore, in many cases, the regressions have little explanatory power. This is suggestive of a threshold effect. When volatility is relatively low, there is little apparent relationship between the volatility of inflation and bond yields, while with higher volatility, the relationship appears stronger.

It is worth examining the empirical implications of these regression results. For the twelve country regressions in Table 5, there is only a single regression that generates a significant estimate of β (namely the regression $\sigma_{84}^2(n_j) = \alpha + \beta\sigma_{84}^2(\pi_j)$ estimated over 1988-95). Using this regression, a 50% fall in the variance of inflation is estimated to lead to a 34% fall in the variance of bond yields.[7] This is, however, the largest predicted fall in the variance of bond yields in the table. All the other estimates imply that halving the variance of inflation leads to a much smaller fall in the variance of bond yields.

7 This estimate is evaluated at the average, over the twelve countries, of the variance of inflation.

Table 5

The volatility of inflation and the volatility of nominal bond yields

(cross-country regressions, 12 countries)

	Levels $\overline{\sigma}_{12}^2(n_j) = \alpha + \beta\overline{\sigma}_{12}^2(\pi_j)$			**Differences** $\Delta\overline{\sigma}_{12}^2(n_j) = \alpha + \beta\Delta\overline{\sigma}_{12}^2(\pi_j)$		
	α	β	R^2	α	β	R^2
1973-80	0.017	0.12**	0.66	-	-	-
	(0.12)	(0.028)				
1981-87	0.39*	0.18	0.17	0.26*	0.046	0.12
	(0.19)	(0.13)		(0.12)	(0.039)	
1988-95	0.21*	0.38	0.14	- 0.10	0.20	0.16
	(0.11)	(0.29)		(0.18)	(0.14)	
	Levels $\sigma_{84}^2(n_j) = \alpha + \beta\sigma_{84}^2(\pi_j)$			**Differences** $\Delta\sigma_{84}^2(n_j) = \alpha + \beta\Delta\sigma_{84}^2(\pi_j)$		
	α	β	R^2	α	β	R^2
1973-80	1.76**	- 0.007	0.004	-	-	-
	(0.50)	(0.032)				
1981-87	3.49*	0.11	0.11	3.18**	0.088	0.07
	(1.61)	(0.10)		(1.05)	(0.098)	
1988-95	0.62	0.58**	0.57	- 1.29	0.17	0.19
	(0.48)	(0.16)		(1.66)	(0.11)	

Notes: 1. Standard errors are presented in parentheses below the coefficient estimates.
2. The 12-month-ended variances are averages for the three sub-periods. The first sub-period starts in January 1974, with the exception of the United Kingdom (November 1976).
3. 84-month variances are calculated over the periods: January 1974 to December 1980, July 1981 to June 1988, and July 1988 to June 1995. Data for the United Kingdom start in January 1976.
4. * and ** indicate that coefficients are significantly different from zero at 10% and 5%, respectively.
5 The regressions are over the same 12 countries as in Table 2.

There is a theoretically compelling reason to expect the elasticity of the variance of bond yields with respect to the variance of the inflation rate, $\varepsilon_{n\pi}$, to be less than one. Any variation in expected real yields over time acts to reduce this elasticity.[8] Nevertheless, the small apparent response of bond yield volatility to changes in inflation volatility should be disappointing to those who argue that volatile asset prices are primarily a consequence of volatile economic fundamentals. Furthermore, rationalising the small apparent response in terms of time-varying real yields is simply an admission of ignorance, since the time variation of expected real yields is unobservable.

To summarise, the evidence that countries with more volatile inflation rates also have more volatile bond yields is strongest when countries with very volatile inflation rates are included in the sample. When they are excluded, there is still some evidence that more volatile inflation rates generate more volatile bond yields. Consistent with this evidence, the fall in inflation volatility in most countries in the OECD has occurred at the same time as a (proportionately smaller) fall in bond yield volatility. However, it is also clear that the empirical relationship between the volatility of

8 From equation (6), it follows that $\varepsilon_{n\pi} = \sigma_T^2(\pi_j^e) / \left[\sigma_T^2(r_j) + \sigma_T^2(\pi_j^e) + 2\sigma_T(r_j, \pi_j^e)\right]$, with obvious notation. Provided $\sigma_T(r_j, \pi_j^e) > -\frac{1}{2}\sigma_T^2(r_j)$, which seems likely, the elasticity must be less than one, and falls as $\sigma_T^2(r_j)$ rises.

inflation and the volatility of nominal bond yields is much weaker than the relationship between the level of inflation and the level of bond yields.

1.2 The foreign exchange market

We turn now to the foreign exchange market. Again, to set the scene for the discussion of volatility to follow, we begin with the relationship between the level of the exchange rate and the relative domestic and foreign price levels.

The theory of purchasing power parity (PPP) asserts that nominal exchange rates move to offset inflation differentials between countries. As is well known, for countries with moderate inflation rates, PPP provides almost no guidance for exchange rate movements over short periods: a month, a quarter or even a year. Over longer periods of time, however, it does provide some guide for exchange rate movements. We test PPP over the three sub-periods, 1973-80, 1981-87 and 1988-95, and over the time period as a whole, 1973-95. To do so, we run the regression:

$$\Delta_{\%}E_j = \alpha + \beta\Delta_{\%}(P^f / P^d)_j, \tag{8}$$

where $\Delta_{\%}E_j$ is the percentage change in the j-th exchange rate from the beginning of the period to its end, E_j is the foreign currency price of a unit of domestic currency, and $\Delta_{\%}(P^f / P^d)_j$ is the percentage change in the ratio of foreign to domestic consumer prices. The results of estimating equation (8) for five exchange rates are shown in Table 6.[9]

Table 6

Testing purchasing power parity
(regressions over 5 exchange rates)

	$\Delta_{\%}E_j = \alpha + \beta\Delta_{\%}(P^f / P^d)_j$		
	α	β	R^2
1973-80	- 10.91 (16.21)	0.03 (0.79)	0.001
1981-87	- 8.9 (5.12)	1.70** (0.40)	0.86
1988-95	0.23 (7.03)	1.96 (0.88)	0.62
1973-95	18.08 (22.73)	2.01* (0.76)	0.70

Note: The variables in the regression are calculated from the first to the last month in each period. * and ** indicate that coefficients are significantly different from zero at 10% and 5%, respectively. The regressions use 5 exchange rates and their corresponding price differentials: A$/US$, US$/¥, US$/DM, £/US$ and US$/Can.$. Exchange rates and inflation differentials which include the United Kingdom start in December 1974.

9 We restrict the sample to five independent exchange rates, because adding cross-rates to the regression does not add any new information. Thus, for example, for countries A, B, and C, the monthly percentage change in exchange rate AC is (approximately) equal to the sum of the monthly percentage changes in exchange rates AB and BC. The majority of exchange rates used for the regressions floated throughout the period 1973-95. The Australian dollar, however, although fairly flexible, was not floated until 1983. Thus, when the Bretton Woods system broke down in 1973, Australia maintained its peg to the US dollar. By 1974, the peg was changed to one with a basket of currencies. This system again changed in 1976, and from then until 1983 the Australian dollar was on a crawling peg (adjusted daily) against the US dollar.

The equation has almost no explanatory power in the period immediately following OPEC I, 1973-80. It performs quite well, however, over the second and third time periods, 1981-87 and 1988-95. Over these sub-periods and over the period as a whole, 1973-95, β is insignificantly different from unity and the regressions explain a substantial part of the variation in exchange rate changes.

We turn now to exchange rate volatility. From the perspective of economic theory, it is the volatility of the inflation differential between two countries, rather than the volatility of inflation in either country on its own, that should be relevant to the volatility of the exchange rate between them. All exchange rate models predict that nominal shocks that have an effect on the inflation differential between two countries will also affect their bilateral exchange rate. We should also expect the link between the volatility of inflation differentials and exchange rate volatility to be a strong one. With sticky goods prices in each country, nominal shocks should have a disproportionate effect on exchange rate volatility, because asset market equilibrium requires the exchange rate to adjust more in the short run than in the long run (Dornbusch, 1976). This effect is also strengthened because, given the inertia of the inflation process, a positive inflation shock implies not only a higher price level, but also a higher rate of inflation for some time into the future. With a forward-looking foreign exchange market, this again implies a disproportionate exchange rate response to inflation shocks (Lyons, 1990).

As we have seen earlier in Figure 2, the variability of inflation rates across the OECD fell steadily in the 1990s, and by 1995 was lower than at any time in the past quarter of a century. Not surprisingly, this generalised decline in inflation variability is also manifest in a decline in the volatility of inflation differentials between many pairs of countries. Table 7 shows the volatility of inflation differentials for six country pairs. As the table shows, the volatility of the inflation differential for these six country pairs declines by between 40 and 70% from 1973-87 to 1988-95. Table 7 also shows the volatility of the exchange rates for the same six country pairs. As is clear from the table, the pattern of exchange rate volatilities is markedly different from the pattern of inflation differential volatilities. By contrast with inflation differential volatilities, there is little systematic change in exchange rate volatilities from 1973-87 to 1988-95, with three exchange rates exhibiting a decline in average volatility and three experiencing a rise.

Figure 4 shows an equally striking example of the apparent lack of relationship between the volatility of the inflation differential and exchange rate volatility. Despite a huge fall in the volatility of the US/Japan inflation differential between the mid-1970s and the 1990s, there is no apparent change in the volatility of the US dollar/yen exchange rate.

We can also test this conclusion with regression analysis. In Tables 8 and 9 we report the results of a range of regressions similar to those presented above for the bond market. In each regression a measure of exchange rate volatility is regressed on a measure of the volatility of the inflation differential between the relevant two countries. Using period averages over the same three time periods as before, we perform cross-exchange rate regressions over thirteen exchange rates.[10]

10 The thirteen exchange rates include the independent exchange rates used for Table 6 (with the exception of the US$/Can.$ - excluded because, in terms of volatility, it appears to be a special case, perhaps because of the overwhelming role of the United States in Canadian trade) plus several cross-rates. Cross-rates may be included in the regression for the following reason. While the monthly percentage change in exchange rate AC is (approximately) equal to the sum of the monthly percentage changes in exchange rates AB and BC, the same statement is not true for the variance of monthly percentage changes, because there is also a covariance term. As a consequence, including cross-rates in the regression adds new information.

Table 7

Volatility in inflation differentials and exchange rates

	Inflation differential volatilities			Percentage change 1973-87 to 1988-95
	1973-80	1981-87	1988-95	
Australia/United States	1.2	1.2	0.7	- 44.4
Australia/Japan	2.0	1.0	0.7	- 52.4
Australia/Germany	1.5	0.9	0.7	- 42.3
United States/Japan	1.6	0.7	0.4	- 69.3
Germany/Japan	1.7	0.7	0.4	- 63.1
United States/Germany	0.9	0.7	0.4	- 54.2
	Exchange rate volatilities			**Percentage change 1973-87 to 1988-95**
	1973-80	**1981-87**	**1988-95**	
A$/US$	2.3	2.9	2.5	- 1.8
A$/¥	3.4	3.7	3.9	9.6
A$/DM	3.5	3.6	4.3	21.0
US$/¥	3.0	3.2	3.1	- 1.2
DM/¥	3.3	2.9	2.6	- 15.5
US$/DM	3.3	3.2	3.3	2.2

Note: Inflation differential volatility is the average, over each period, of 12-month-ended standard deviations of the difference between the respective countries' 12-month-ended percentage change in consumer prices. Exchange rate volatility is the average, over each period, of 12-month-ended standard deviations of monthly percentage changes in the exchange rate. The first period starts in January 1974.

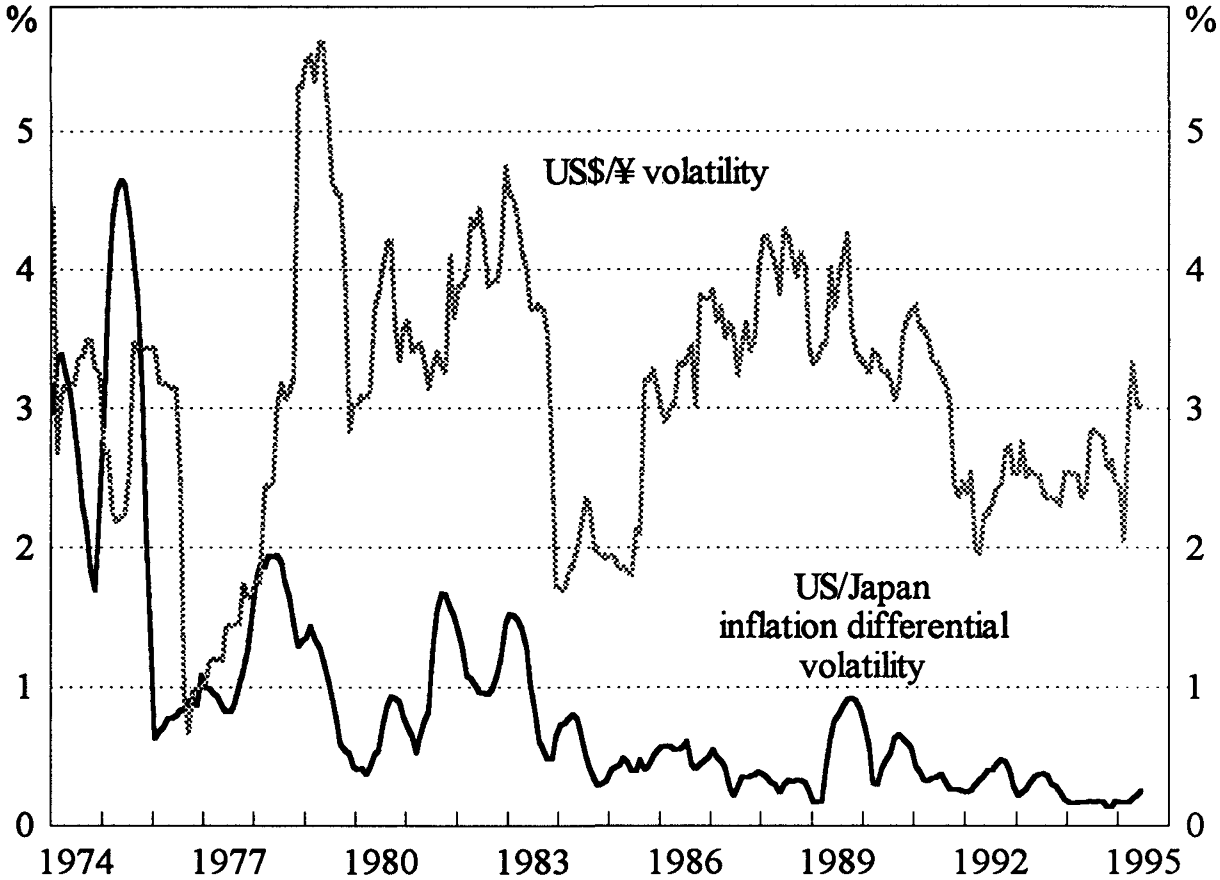
Two things stand out from the results in the tables. Firstly, although the coefficient β is almost always of the expected positive sign - implying that higher exchange rate volatility is correlated with higher volatility of inflation differentials - it is almost always statistically insignificant. Secondly, since most of the regression R^2's in the two tables are less than 0.1, very little of the cross-exchange rate variation in volatility is explained by variation in the volatility of the corresponding inflation differential.

As we did for bond market volatility, we can also examine the empirical implications of these regression results. Of the regressions in the two tables, the regression $\sigma^2_{84}(\Delta e) = \alpha + \beta\sigma^2_{84}(\pi^f - \pi^d)$ estimated over 1988-95 generates the most significant estimate of β. Using this regression, a 50% fall in the variance of the inflation differential between two countries is estimated to lead to a 14% fall in the variance of their bilateral exchange rate.[11] Note, however, both that this is quite a small estimated fall in exchange rate variance, and that it is the largest predicted fall in the variance of the exchange rate in the table. All the other estimates imply that halving the variance of the inflation differential leads to a much smaller fall in the variance of the corresponding exchange rate.

11 This estimate is evaluated at the average, across the thirteen country pairs, of the variance of inflation differentials. As before, given the form of the regression equation, the estimated elasticity of the variance of monthly exchange rate changes with respect to the variance of the inflation differential must be less than unity. Recall that using a similar methodology in the bond market, a 50% fall in the variance of inflation is estimated to lead to a 34% decline in the variance of bond yields.

Figure 4

The volatility of the US/Japan inflation differential and the US$/¥ exchange rate



Note: The US/Japan inflation differential volatility is the standard deviation, over the past 12 months, of monthly readings of the difference between Japanese and US 12-month-ended inflation. Exchange rate volatility is the standard deviation, over the past 12 months, of the monthly percentage change in the US$/¥ exchange rate.

We may summarise our results for the foreign exchange market as follows. Other things equal, economic theory predicts that a decline in the volatility of the inflation differential between countries should reduce the volatility of their bilateral exchange rates. With sticky goods prices in each country, this link between the volatilities of inflation differentials and exchange rates should be particularly strong. Empirically, however, for OECD countries with moderate inflation rates, there is little evidence that the volatility of inflation differentials helps explain exchange rate volatility. While inflation differences between countries that persist for several years make an important difference to the *level* of their bilateral exchange rates, differences in the volatility of inflation differentials for the same group of countries make little, if any, difference to their bilateral exchange rate volatilities. Similarly, the big fall in the volatility of the inflation differential between many pairs of countries in the late 1980s and 1990s has been associated with little, if any, systematic fall in the volatility of their bilateral exchange rates.

Table 8

The volatility of inflation differentials and the volatility of exchange rates
(regressions over 13 exchange rates)

	Levels $\overline{\sigma}^2_{12}(\Delta e)=\alpha+\beta\overline{\sigma}^2_{12}(\pi^f-\pi^d)$			**Differences** $\Delta\overline{\sigma}^2_{12}(\Delta e)=\alpha+\beta\Delta\overline{\sigma}^2_{12}(\pi^f-\pi^d)$		
	α	β	R^2	α	β	R^2
1973-80	10.21**	0.42	0.07	-	-	-
	(1.67)	(0.45)				
1981-87	11.21**	0.08	0.000	- 0.10	0.11	0.005
	(1.71)	(1.43)		(1.22)	(0.44)	
1988-95	9.13**	6.12	0.15	3.24*	3.74	0.20
	(2.62)	(4.38)		(1.53)	(2.29)	
1973-95	9.53**	1.35	0.08	-	-	-
	(2.39)	(1.36)				
	Levels $\overline{\sigma}_{12}(\Delta e)=\alpha+\beta\overline{\sigma}_{12}(\pi^f-\pi^d)$			**Differences** $\Delta\overline{\sigma}_{12}(\Delta e)=\alpha+\beta\Delta\overline{\sigma}_{12}(\pi^f-\pi^d)$		
	α	β	R^2	α	β	R^2
1973-80	2.73**	0.26	0.09	-	-	-
	(0.41)	(0.25)				
1981-87	3.18**	0.01	0.000	0.15	0.16	0.05
	(0.41)	(0.45)		(0.17)	(0.22)	
1988-95	2.66**	1.11	0.09	- 0.33**	- 0.07	0.06
	(0.68)	(1.06)		(0.07)	(0.09)	
1973-95	2.74**	0.51	0.05	-	-	-
	(0.66)	(0.66)				

Notes: 1. Standard errors are presented in parentheses below the coefficient estimates.
2. * and ** indicate that coefficients are significantly different from zero at 10% and 5%, respectively.
3. In the upper panel, the average, over each period, of 12-month-ended *variances* of monthly exchange rate percentage changes is regressed on the average, over each period, of 12-month-ended *variances* of 12-month-ended inflation differentials, while in the lower panel, the average, over each period, of 12-month-ended *standard deviations* of monthly exchange rate percentage changes is regressed on the average, over each period, of 12-month-ended *standard deviations* of 12-month-ended inflation differentials.
4. The regressions use 13 exchange rates and their corresponding inflation differentials: A$/US$, A$/¥, A$/DM, A$/Can.$, A$/£, DM/¥, US$/¥, Can.$/¥, £/¥, US$/DM, £/US$, Can.$/DM and £/Can.$.
5. The first period starts in January 1974, with the exception of the United Kingdom (November 1976).

Table 9

The volatility of inflation differentials and the volatility of exchange rates
(regressions over 13 exchange rates)

	Levels $\sigma^2_{84}(\Delta e)=\alpha+\beta\sigma^2_{84}(\pi^f-\pi^d)$			Differences $\Delta\sigma^2_{84}(\Delta e)=\alpha+\beta\Delta\sigma^2_{84}(\pi^f-\pi^d)$		
	α	β	R^2	α	β	R^2
1973-80	9.58**	0.10	0.15			
	(1.15)	(0.07)				
1981-87	12.33**	0.06	0.003	2.35*	0.07	0.05
	(1.56)	(0.34)		(1.31)	(0.09)	
1988-95	8.57**	0.82**	0.34	- 0.83	0.33	0.17
	(1.59)	(0.34)		(0.70)	(0.23)	
1973-95	9.37**	0.20	0.09	-	-	-
	(2.35)	(0.20)				
	Levels $\sigma_{84}(\Delta e)=\alpha+\beta\sigma_{84}(\pi^f-\pi^d)$			**Differences** $\Delta\sigma_{84}(\Delta e)=\alpha+\beta\Delta\sigma_{84}(\pi^f-\pi^d)$		
	α	β	R^2	α	β	R^2
1973-80	2.93**	0.10	0.13			
	(0.30)	(0.08)				
1981-87	3.34**	0.10	0.02	0.37*	0.08	0.07
	(0.37)	(0.19)		(0.20)	(0.09)	
1988-95	2.67**	0.38*	0.24	- 0.13	0.25	0.20
	(0.41)	(0.21)		(0.10)	(0.15)	
1973-95	2.77**	0.18	0.08	-	-	-
	(0.64)	(0.19)				

Notes: 1. Standard errors are presented in parentheses below the coefficient estimates.
2. * and ** indicate that coefficients are significantly different from zero at 10% and 5%, respectively.
3. In the upper panel, the average *variance*, over the 84 months in each period, of monthly exchange rate percentage changes is regressed on the average *variance*, over the 84 months in each period, of 12-month-ended inflation differentials, while in the lower panel, the average *standard deviation*, over the 84 months in each period, of monthly exchange rate percentage changes is regressed on the average *standard deviation*, over the 84 months in each period, of 12-month-ended inflation differentials.
4. The regressions use 13 exchange rates and their corresponding inflation differentials: A$/US$, A$/¥, A$/DM, A$/Can.$, A$/£, DM/¥, US$/¥, Can.$/¥, £/¥, US$/DM, £/US$, Can.$/DM and £/Can.$.
5. The 84-month variances (standard deviations) are calculated over the periods: January 1974 to December 1980, July 1981 to June 1988, and July 1988 to June 1995. Exchange rates including the United Kingdom start in January 1976.

2. What can economists say about financial market volatility?

In seeking to understand volatility in bond and foreign exchange markets, it is of interest to touch on the wider debate about financial market volatility. There has been a lively academic debate, given initial impetus by Shiller (1981) and LeRoy and Porter (1981), about whether financial market volatility is "excessive" or not. The debate focuses primarily on the stock market and on the issue of whether the volatility of stock prices can be justified by the volatility of the discounted stream of future dividends. Ultimately, the relevant statistical tests have a joint null hypothesis of market efficiency and a specific model of the discount rate used to discount future dividends.[12] As a consequence, when the data imply rejection of this joint hypothesis (as they invariably do) it is not clear whether this is a demonstration that financial market volatility is indeed excessive, compared to the volatility to be expected of an efficient market, or instead, simply a rejection of the specific model of the discount rate (see Shiller, 1989, and comments on Shiller by Cochrane, 1991).

There is, however, other evidence about the nature of asset market volatility provided by two "events" in the stock market. Although not new, this evidence is compelling and hence worth examining. The first event is a paperwork backlog (!) at the New York and American Stock Exchanges, which led these exchanges to be closed on Wednesdays during the second half of 1968.

French and Roll (1986) use this event to compare the movement of stock prices from the Tuesday close of the exchange to the Thursday close in weeks when the exchange was closed on Wednesday because of the paperwork backlog, with the movement in weeks when it was open. Paperwork backlogs at the stock exchange should be irrelevant to the Tuesday-close-to-Thursday-close performance of companies listed on the exchange. Hence, if stock prices move solely because of the arrival of new relevant information about the companies listed, then the average variance of stock returns in a two-day period including a Wednesday exchange holiday should be the same as an average two-day period with the exchange open on both days, or equivalently, twice the variance of an average single day on which the exchange is open.[13] In fact, French and Roll find that the average variance of stock prices over two days including an exchange holiday is much closer to the variance over an average single day than an average two-day period with the exchange open on both days.[14]

The second event that casts light on asset market volatility is the 1987 stock market crash. Based on questionnaires completed in its aftermath by both institutional and individual investors, Shiller (1988) concludes that: "no news event, other than news of the crash itself, precipitated the crash. Rather, the dynamics of stock market prices seem to have more to do with the internal dynamics of investor thinking, and the medium of communications among large groups of investors is price. In a period when there is a widespread opinion that the market is under or overpriced, investors are standing ready to sell. It takes only a nudge in prices, something to get them reacting, to set off a major market move" (p. 15).

Clearly, neither of these examples implies that asset prices do not respond to changes in economic fundamentals. They do, however, provide compelling evidence that some of the short-term movement in asset markets cannot be explained in terms of the efficient incorporation of public

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12 For example, two common specific models are that the discount rate is constant through time, or that it is equal to the real interest rate plus a constant risk premium.

13 With stock price movements closely approximating a random walk, the average variance over two days is twice the average variance over a single day.

14 The average two-day variance spanning an exchange holiday is 14.5% higher than an average single "open" day, whereas an average two-day period with the exchange open on both days has a variance of stock price movements 75% higher than a two-day period spanning an exchange holiday.

information about fundamentals. Instead, at least some asset price volatility appears to arise from the process of trading introducing noise into asset prices.[15]

Returning to volatility in the bond and foreign exchange markets, it is worth commenting on economists' different level of understanding of these two markets. In the bond market, there is little controversy about the determinants of bond yields. There is a simple underlying model of nominal bond yields and agreement among economists about the explanatory power of this model. As we have discussed, the nominal bond yield can usefully be decomposed into the expected real yield and expected inflation over the life of the bond. Although risk premia differ between countries, expected real yields on government long bonds are similar in OECD countries with open capital markets and infinitesimal risks of default. Furthermore, expected future inflation responds, probably with a lag, to actual inflation, so that differences in actual inflation explain a substantial part of differences in nominal bond yields between countries (Tables 1 and 2). Although the bond market moves in puzzling ways at times, with 1994-95 being a prime example, economists are rightly confident that they have a good understanding of the economic forces that determine bond yields.

Unfortunately, the same cannot be said of the foreign exchange market. For OECD countries with moderate inflation rates, it is true that PPP provides some guide for movements in floating exchange rates over many years (Table 6). Over shorter periods of time, however, there is simply no underlying model, agreed upon by economists, that explains the movement of exchange rates. Instead, exchange rates are apparently subject to a myriad of influences, and there has been little success uncovering the economic fundamentals - or, for that matter, other forces - that determine their shorter-term movements. As Richard Meese (1990) puts it: "The proportion of (monthly or quarterly) exchange rate changes that current models can explain is essentially zero. Even after-the-fact forecasts that use *actual values (instead of forecasted values) of the explanatory variables* cannot explain major currency movements over the post-Bretton Woods era. This result is quite surprising." (italics added)

The extent to which fundamentals explain the shorter-term movements of bond yields and exchange rates is relevant to understanding volatility in these two markets. In the bond market, where economic fundamentals provide a convincing explanation for much of the movement of bond yields, one might reasonably expect a change in economic fundamentals - like a fall in the volatility of inflation - to have a significant and predictable influence on bond yield volatility. By contrast, in the foreign exchange market, where, for reasons that are not fully understood, economic fundamentals apparently explain very little of the movement of exchange rates over times of relevance to volatility, one should be less confident that changes in economic fundamentals will have a measurable influence on market volatility.

These observations accord quite well with our empirical results. The worldwide fall in the 1990s in the volatility of inflation seems to have been responsible for at least some fall in the volatility of bond yields. By contrast, and notwithstanding the predictions of economic theory, there has been little, if any, fall in the volatility of exchange rates despite a substantial fall in the volatility of inflation differentials between countries.

15 It is beyond our scope to discuss the social costs of excessive financial market volatility. Even if there is substantial volatility introduced by the process of trading, however, the associated social costs may be small (Cochrane, 1991, pp. 20-23).

DATA APPENDIX

Data for long-term nominal interest rates are as follows:

Australia	10-year Treasury bond yield, RBA Bulletin, Table F.2.
Belgium	Interest rate on 5-year central government bonds, OECD.
Canada	Interest rate on 10-year federal government bonds (Wednesday average), OECD.
Denmark	Interest rate on 10-year government bond (end-period), OECD.
Germany	Interest rate on public sector bonds with 7 to 15 years to maturity, OECD.
Finland	Long-term interest rate on taxable public bonds with 3 to 6 years to maturity (monthly average), OECD.
France	Interest rate on government bonds with over 7 years to maturity (monthly average), OECD.
Ireland	Interest rate on central government bonds with 5 years to maturity, OECD.
Italy	Yield on Treasury bonds with average maturity of 2.5 years, OECD.
Japan	Compound interest rate on government bonds with 8 to 10 years to maturity (month-end), Datastream.
New Zealand	Interest rate on 10-year government bonds (month-end), OECD.
Norway	Interest rate on central government bonds with 6 to 10 years maturity (month-end), OECD.
United Kingdom	Interest rate on 10-year government bonds, OECD.
United States	10-year (constant maturity) bond yield, OECD.

Inflation data and their sources are as follows:

Australia	Australian underlying inflation (Treasury series). For empirical analysis requiring a monthly series, we use: Australian manufacturing prices (excluding petrol from July 1979), Australian Bureau of Statistics.
Belgium	All goods less food, OECD.
Canada	All items less food, OECD.
Denmark	All items less food, OECD.
Finland	All items less food, OECD.
France	All items less food, OECD.
Germany	CPI excluding food and energy, Bundesbank.
Greece	All items, OECD.
Ireland	All items, OECD. Data for this series are available quarterly. To construct a monthly series we assume the index is unchanged in the quarter.
Italy	All goods less food, OECD.
Japan	All items less food, OECD.
Luxembourg	All items less food, OECD.
Netherlands	All items less food, OECD.

New Zealand	All items, OECD. Data for this series are available quarterly. To construct a monthly series we assume the index is unchanged in the quarter.
Norway	All items less food, OECD.
Portugal	All items less food and rent, OECD.
Spain	All items less food, OECD.
Sweden	All items, OECD.
United Kingdom	All items excluding mortgage interest payments, Central Statistics Office.
United States	All items excluding food and energy, Department of Labour.

All foreign exchange rates are sourced or derived from the RBA Bulletin Tables F.9 and F.10, except for US dollar/Canadian dollar exchange rates prior to 1980, which come from IMF "International Financial Statistics".

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