

# What's driving correlation?

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# Correlation – some questions

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- Measuring (and forecasting) correlations is an important problem
- Over the next few slides we show a few long term correlation series; we will focus in this talk on the bond / equity correlation story

# Correlations between equity market have increased

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Average pairwise correlation between MSCI World countries – peaked in 2009 but still remains historically high



Source: UBS

# Correlations between equity market have increased

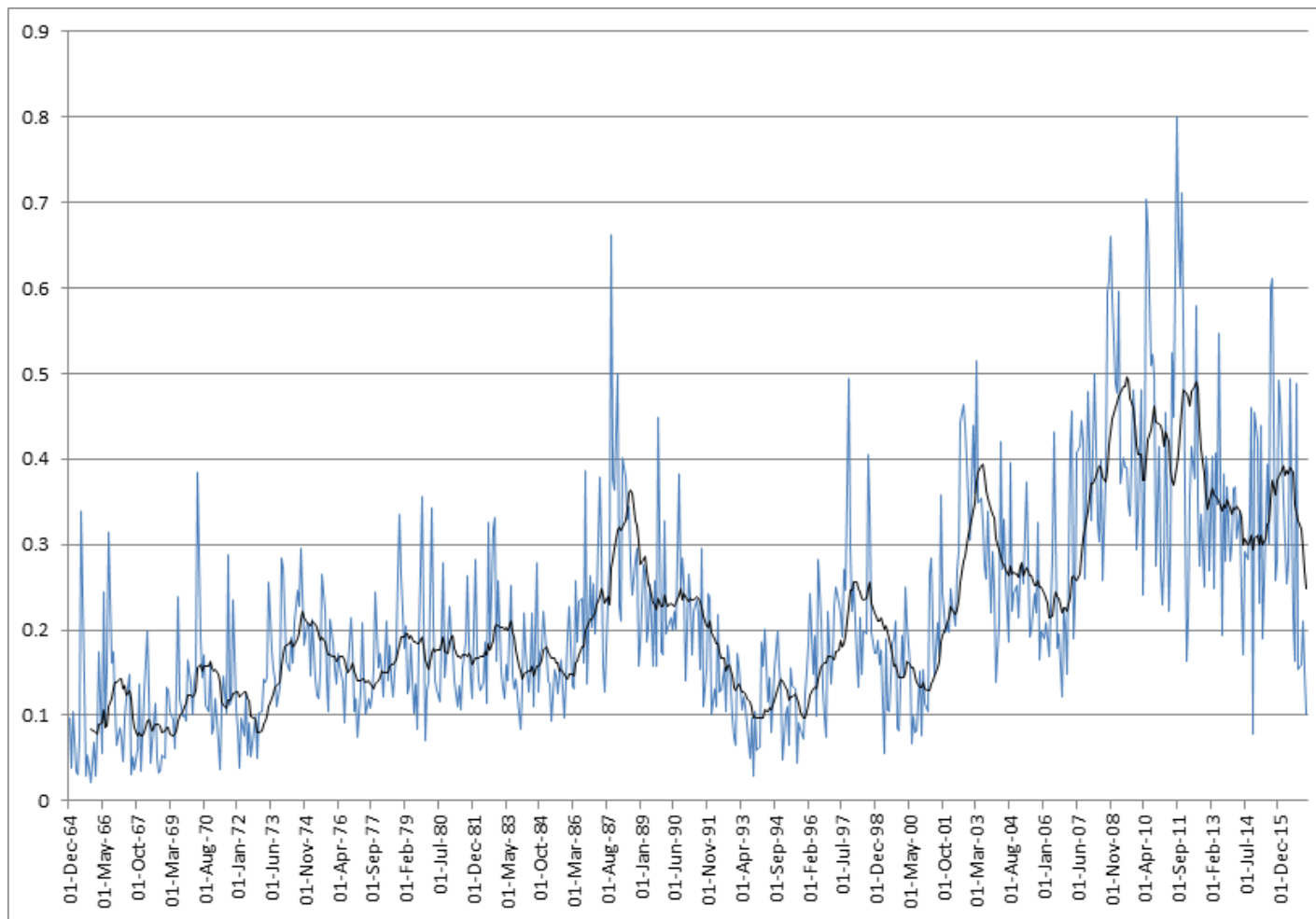
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- And we see the same with shorter term data



# Average correlation within US equities

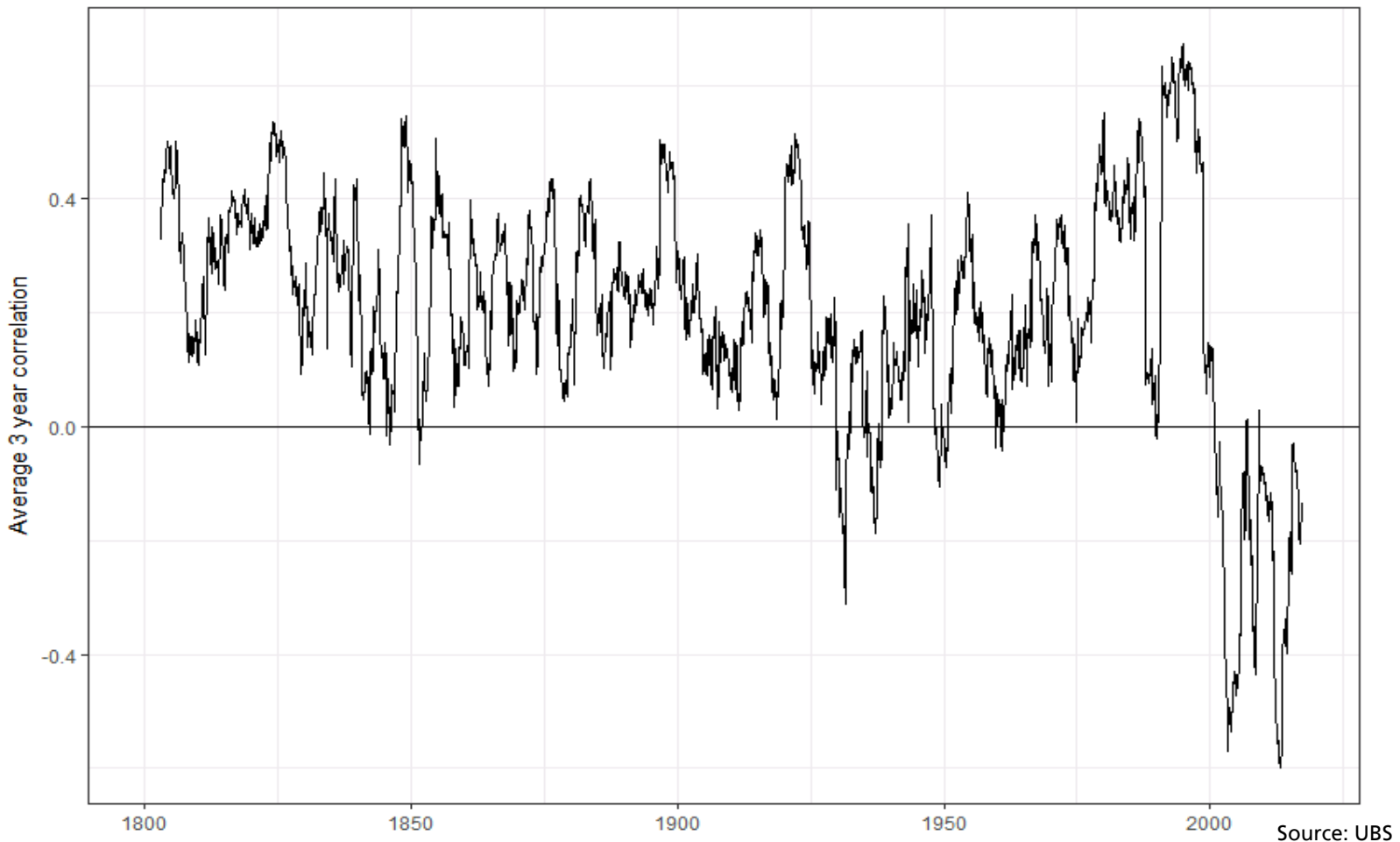
- Correlation rose significantly over the financial crisis – is the fall back to 0.1 a "change of regime"?



# Bond and equity correlation

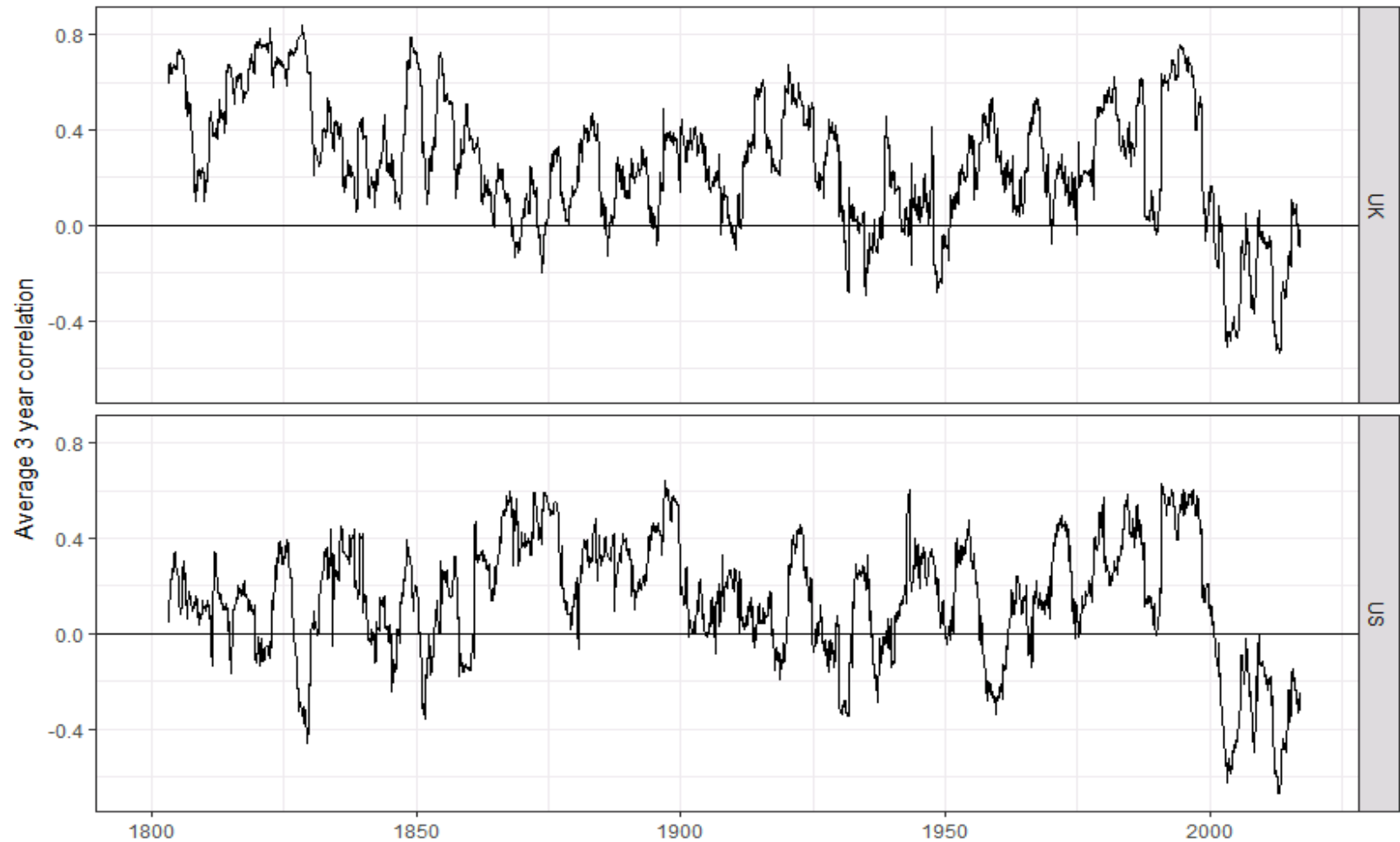
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- Chart shows correlation between bonds and equities (averaged across UK and US) from 1800. This century's negative correlation is unprecedented.



# Bond and equity correlation

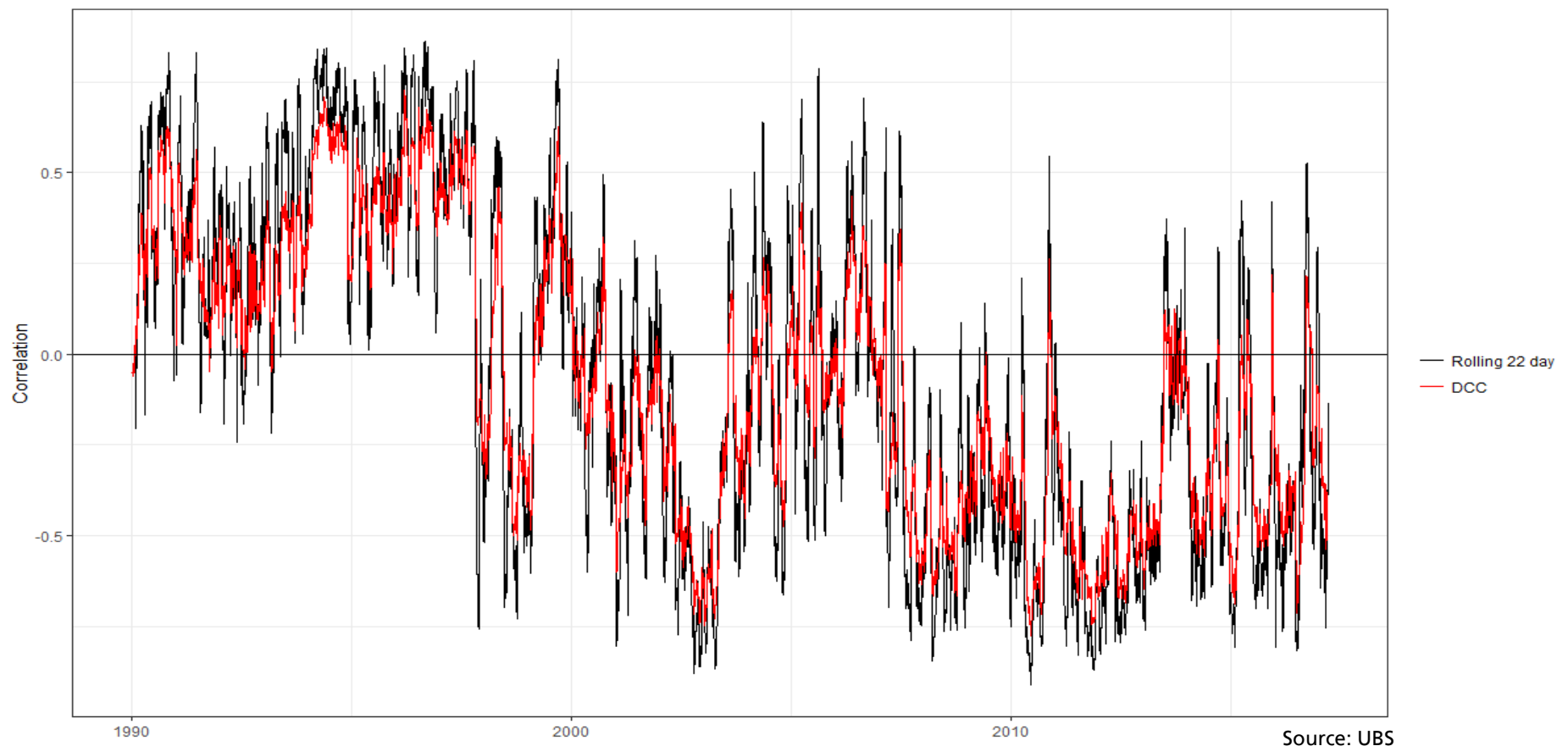
- Separating the UK and US, the US goes negative more often.



Source: UBS

# US Bond vs Equity – shorter term

- Chart shows daily rolling correlation (black) and the correlation estimated from a GARCH-DCC model (red). We see the same change of sign around 2000.





## Section 1

# Bonds vs equities

# Bond vs equity correlation

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- What drives the changing nature of bond vs. equity correlation?
- Various academic papers have looked into this. The suggested drivers include
  - Inflation (expected, unexpected, uncertainty)
  - Volatility (VIX)
  - Recessions
  - Real interest rates
- We will investigate these different macroeconomic effects.

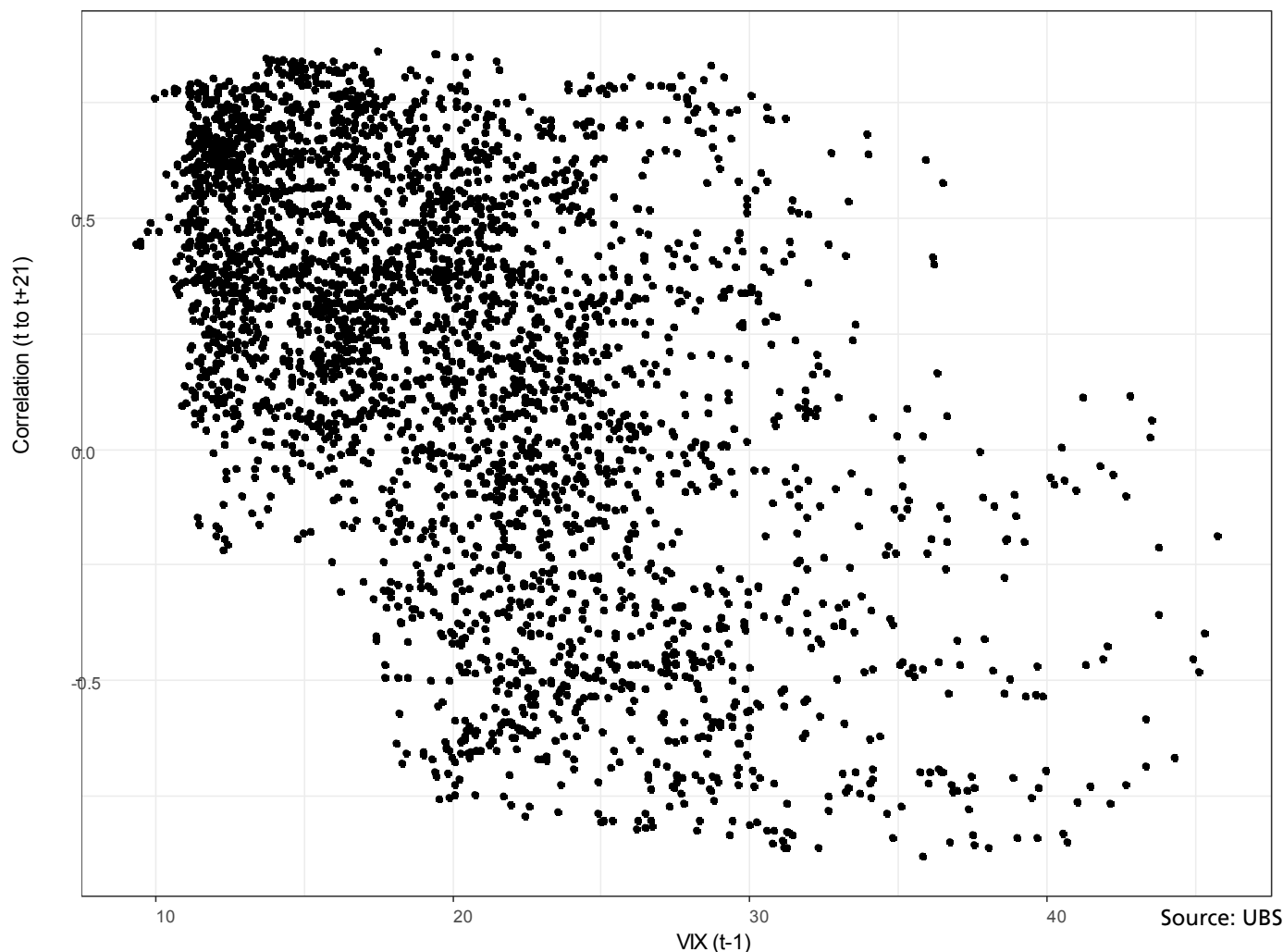
# Volatility

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- The effect of stock implied volatility on the stock-bond correlation was investigated by Connolly et al (2005 & 2007). They suggest "higher stock market uncertainty may be associated with more frequent revisions in investors' assessment of stock risk and the relative attractiveness of stocks vs. bonds. If so, then during times of higher stock market uncertainty it seem plausible that a temporary negative stock-bond return correlation is more likely to be observed."
- Their data goes from 1986-2000 (or to 2002 in the later paper), so ending just as the structural break in correlations occurs. Our daily data is from 1990 – 2017.

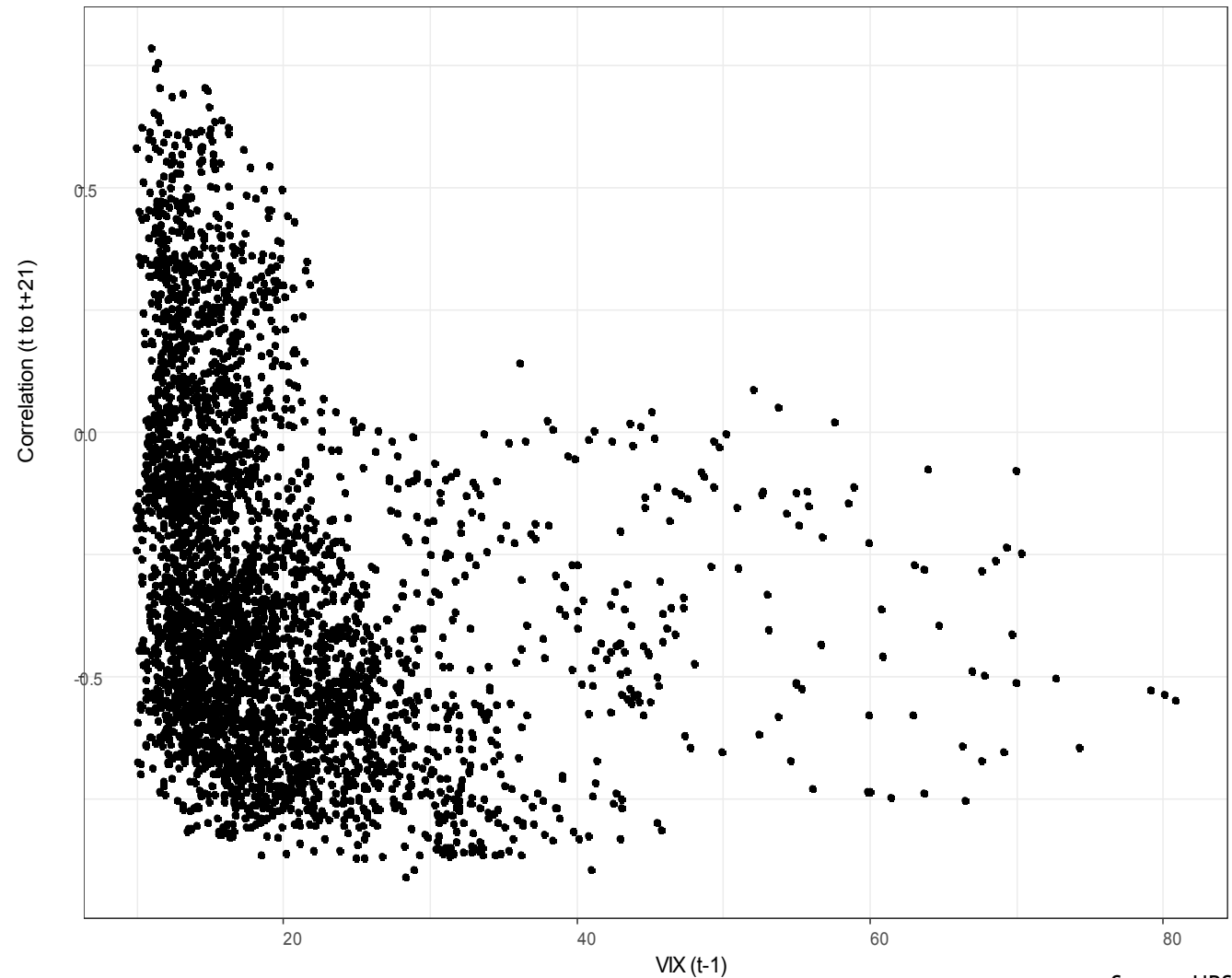
# VIX and Correlation

- Chart shows data from 1990 – 2002 (as in the later paper) – higher VIX apparently leads to lower correlation.
- This done with 22 day rolling correlation; the picture with the DCC correlation is the same.



# VIX and Correlation

- Chart shows data from 2003 to date.
- The picture is similar but a little less convincing.



Source: UBS

# Modelling the interaction

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- The next test was to fit the following regression model
- $B_t = a_0 + (a_1 + a_2 \ln(VIX_{t-1}))S_t + \epsilon_t$
- where  $B_t$  and  $S_t$  are daily returns and  $\ln(VIX_{t-1})$  is the log of the VIX (logs to reduce the skewness). The parameter of interest is  $a_2$  which controls the interaction between today's VIX and tomorrow's stock and bond interaction.
- If  $a_2$  is restricted to zero then this is calculating the beta of bonds to equities. This does not have to imply a causal link. This was pointed out by Barr Rosenberg and James Guy back in 1976 :
  - "from an economic viewpoint, the market return does not cause the security return. Instead, both are caused by economic events. This point has created some confusion among analysts who interpret beta [...] as necessarily stating the causal relationship of market returns upon the security returns: That is, if beta is two, a market return of 10 percent causes a security return of 20 percent. The correct wording of this statement is that, as a consequence of the dependence of both market return and security return upon economic events, if a market return of 10 percent is observed, then the most likely value for the associated security return is 20 percent."

# Modelling the interaction - results

- The relationship changes over time. The sign of  $a_1$  switches from positive to negative after 98; and the coefficient on  $a_2$  from negative to positive after 2008.

	a0	a1	a2	a1+a2 ln(VIX) VIX = 11.5%	a1+a2 ln(VIX) VIX = 17.75%	a1+a2 ln(VIX) VIX = 33.5%
Jan 90-Dec 97	0.0002 (2.28)	0.198 (8.05)				
	0.0002 (2.20)	0.965 (5.12)	-0.259 (-3.87)	0.331	0.219	0.054
Jan 98 - Dec 07	0.0002 (2.88)	-0.084 (-8.00)				
	0.0002 (2.95)	0.317 (3.23)	-0.124 (-4.09)	0.014	-0.040	-0.119
Jan 08 - Mar 17	0.0002 (2.66)	-0.160 (-9.342)				
	0.0003 (2.81)	-0.579 (-6.57)	0.119 (4.44)	-0.288	-0.236	-0.161

Source: UBS

# Changing VIX and correlations

- Correlation tends to become more negative when the VIX is rising. This is dividing the data into subsets (not forward looking).

To Dec 2000						
	n	Mean Bond	SD Bond	Mean Equity	SD Equity	Correlation
0 - 5th %ile	144	0.135	0.399	1.253	1.112	0.331
0 - 25th %ile	717	0.124	0.386	0.764	0.848	0.292
25th - 50th %ile	691	0.056	0.355	0.260	0.580	0.255
50th - 75th %ile	743	0.009	0.335	-0.081	0.595	0.222
75th - 100th %ile	717	-0.071	0.470	-0.695	0.968	0.161
95th - 100th %ile	144	-0.104	0.616	-1.509	1.257	0.059
Jan 98 - Dec 07						
	n	Mean Bond	SD Bond	Mean Equity	SD Equity	Correlation
0 - 5th %ile	131	-0.084	0.437	1.870	1.113	-0.248
0 - 25th %ile	652	-0.044	0.452	1.086	0.950	-0.212
25th - 50th %ile	652	-0.008	0.403	0.240	0.608	-0.015
50th - 75th %ile	652	0.034	0.376	-0.173	0.616	-0.125
75th - 100th %ile	652	0.103	0.466	-1.039	0.988	-0.352
95th - 100th %ile	131	0.225	0.492	-1.886	1.070	-0.522
Jan 08 - Mar 17						
	n	Mean Bond	SD Bond	Mean Equity	SD Equity	Correlation
0 - 5th %ile	121	-0.311	0.539	2.101	1.816	-0.496
0 - 25th %ile	601	-0.183	0.507	1.145	1.239	-0.400
25th - 50th %ile	600	-0.027	0.479	0.339	0.647	-0.187
50th - 75th %ile	600	0.036	0.419	-0.131	0.590	-0.200
75th - 100th %ile	601	0.248	0.546	-1.204	1.299	-0.579
95th - 100th %ile	121	0.522	0.594	-2.377	1.663	-0.723

Source: UBS. The change in VIX is measured by percentage change. The correlation is calculated using a zero mean.



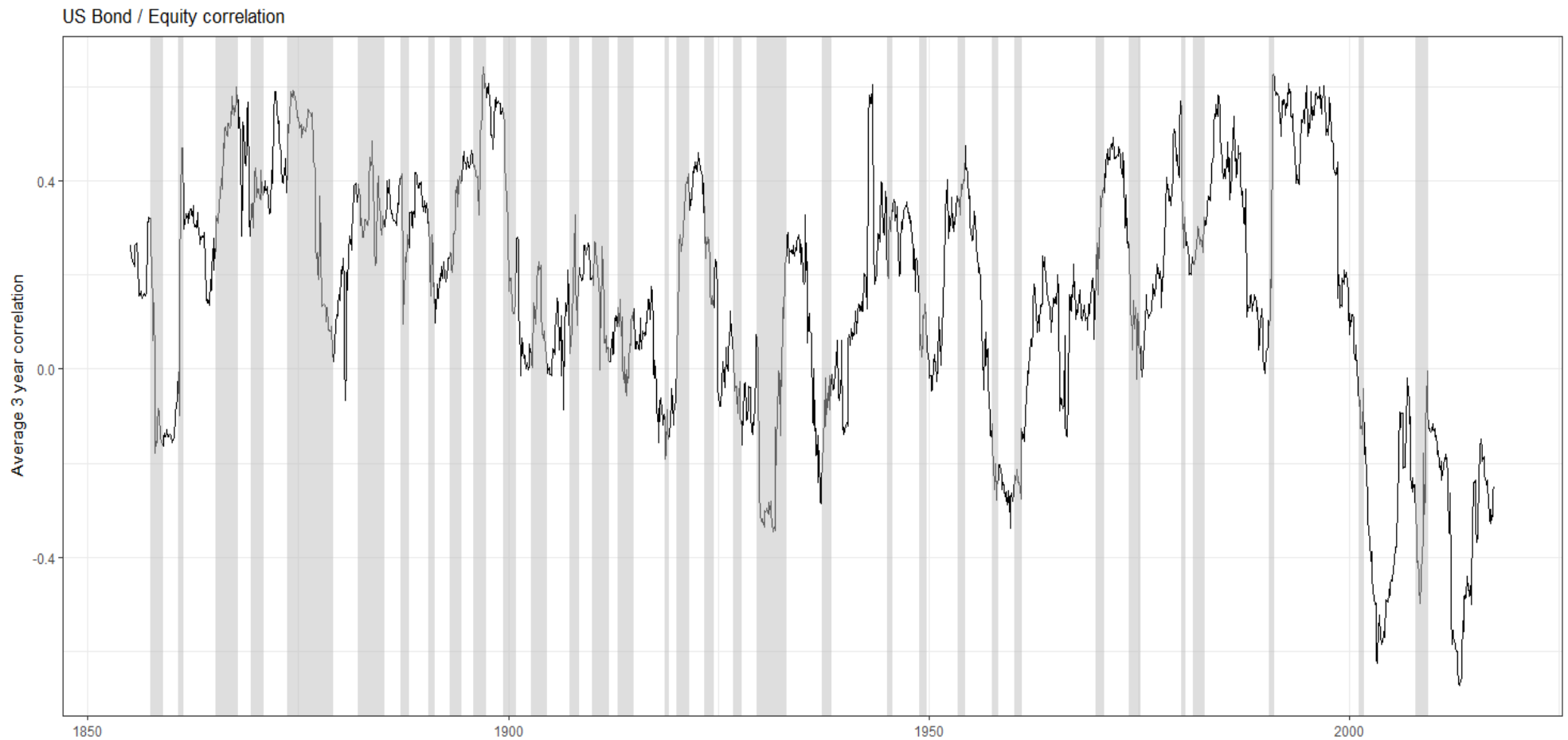
# Recessions

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- Yang et al (2009) investigate the effect of recessions on correlation.
- However the sign of the relationships is not always consistent! They find "in the US, the stock-bond correlations during recessions are lower than those during expansions [...]. By contrast, the high correlations occur during recessions than during expansion in the UK".
- On our data (similar but not exactly the same) over the period from 1857 to date we find that the correlation within US recessions is 0.177 and in expansions is 0.101; if we exclude the data after 2000 these numbers change to 0.215 and 0.183 (Yang has 0.155 and 0.162).
- So our data shows a small increase in correlations during recessions, but the effect is small and seemingly somewhat inconsistent.
- Li (2002) says "the results [using data from 1980 to 2001] do not indicate that the business cycle has any effect on the stock-bond correlation, either in the U.S. or in the G7 panel."

# US Bond vs Equity

- US Equity / Bond correlation and recessions.



Source: UBS, recession dates from NBER

# US Bond vs Equity

- What about inflation? Chart shows 12m change in Core PCE, the Fed's preferred inflation measure. As we are very aware, inflation has remained in the 1-2% range for some time.



Source: UBS, NBER

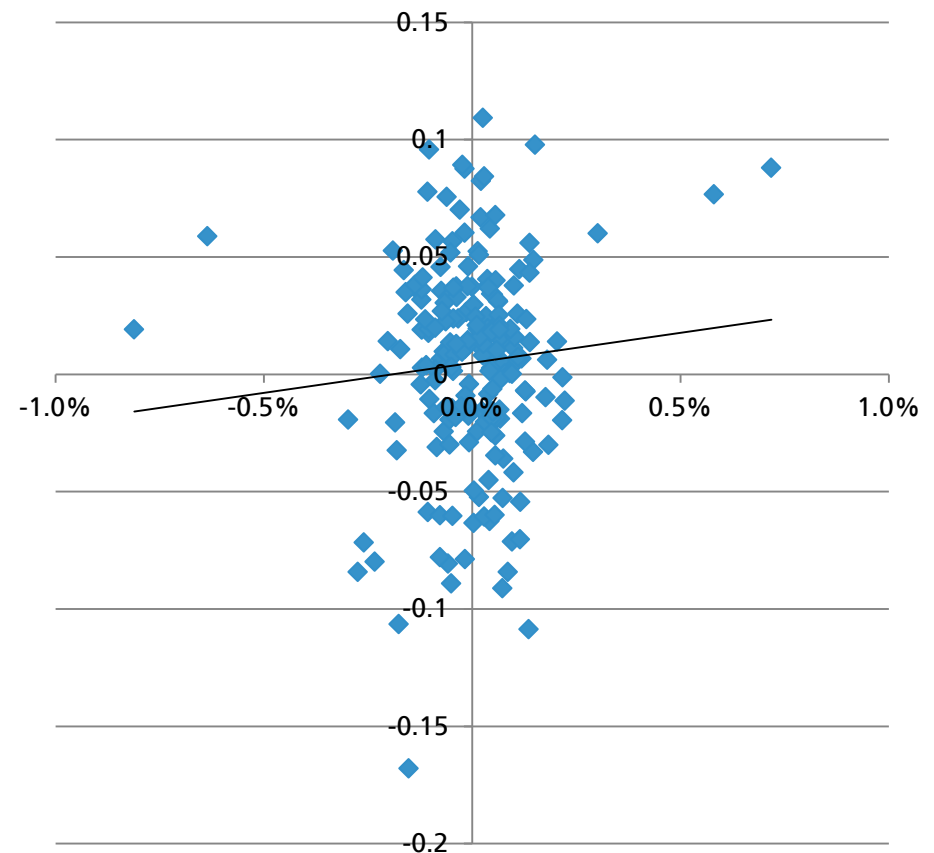
# Inflation

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- Why should inflation have an effect on the stock-bond correlation?
- (Unexpectedly) Higher inflation has a straightforward effect on bonds – which is negative. Higher inflation raises expected future short rates and (potentially) risk premia.
- For equities the story is more complex. If we consider any DCF model then increasing inflation could have no impact if it affects the top line (cash flows) by the same as the bottom line (discount rates). However the effect could have either sign. For example, too high a level of inflation leads to higher discount rates (and potentially lower future growth from monetary policy).
- However at the moment inflation is very low and any increase has been seen as a positive for growth.

# Equity returns and changing inflation

- We see this in these charts: pre-2000 (LHS) inflation increasing was bad for equities; post 2000 it was good. We also see the same effect looking at inflation above and below 2.5%. The charts show the change in annual inflation against next month's S&P 500 return.



Source: UBS. LHS chart data from Jan 1959 to Dec 2000; RHS from Jan 2001 to Jan 2017.

# Modelling unexpected inflation

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- We need to separate inflation into expected and unexpected components. Andersson et al (2008) use consensus economic forecasts (from Consensus Economics).
- Li (2002) produces two measures of expected inflation – a short term one, built from a Bayesian Vector Autoregression (BVAR) model with inputs of trailing inflation, industrial production and the T-bill rate (using 12 lags); and a long term one defined as the spread between long term bond yields and the trailing 5 year real GDP growth rate.
- Wei (2009) builds a model of inflation based on trailing inflation and the unemployment rate.
- Once we have expected inflation we can calculate real interest rates and unexpected inflation.

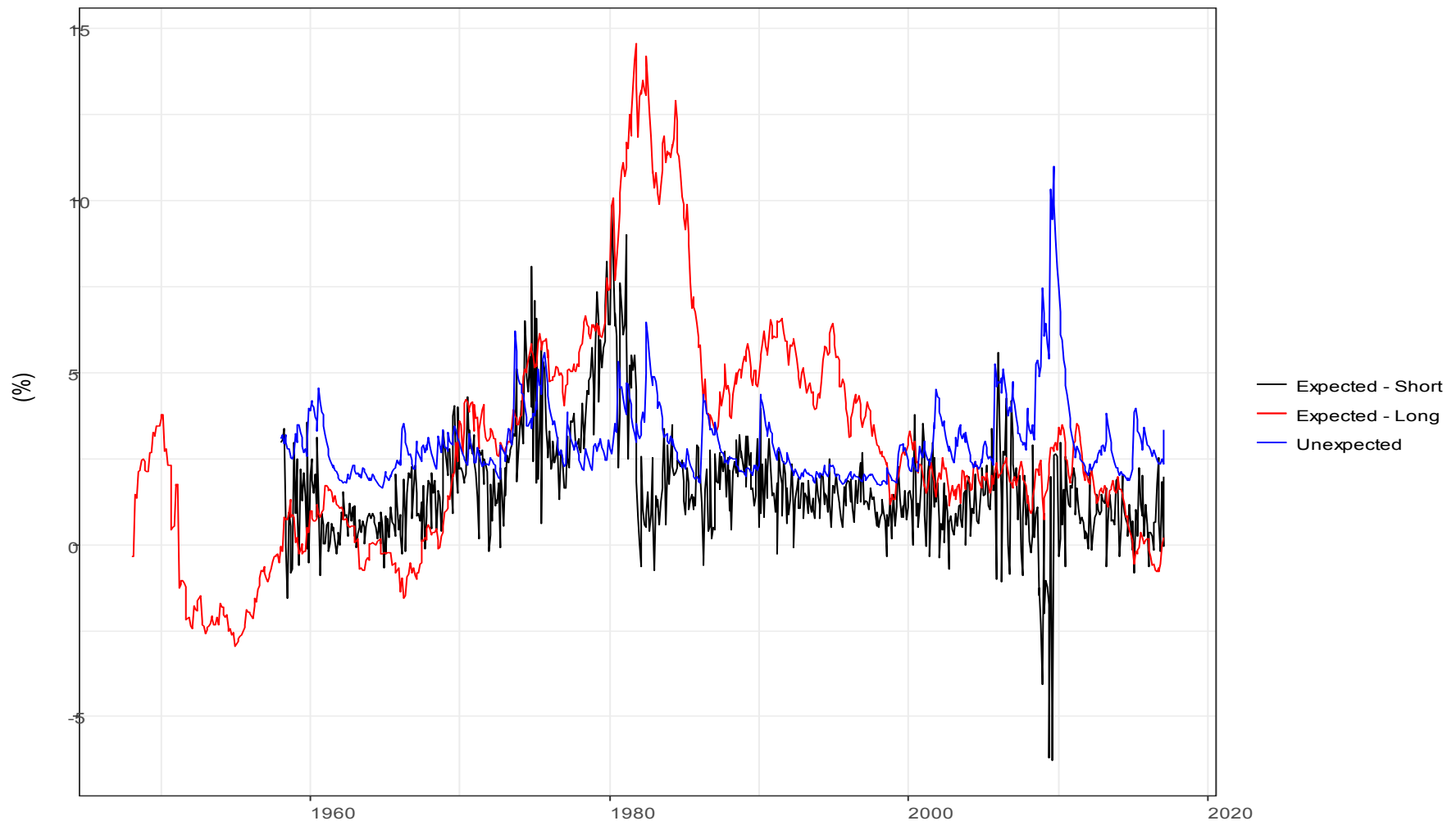
# Uncertainty in inflation

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- Li (2002) goes on to also calculate the uncertainty of inflation. He uses the level of long term expected inflation as a measure of its uncertainty. This was observed in Okun (1971) – higher inflation leads to higher uncertainty of inflation.
- For short term unexpected inflation he uses the volatility from a GARCH(1, 1) model fitted to the short term unexpected inflation.

# Inflation – expected and unexpected

- Chart shows the expected inflation and the volatility of unexpected inflation. Note the scales are adjusted to put the data on one plot.



Source: UBS



# Regression results

- The relationship with expected inflation has changed; historically it was positive; now it's negative – so increasing expected inflation now decreases correlation. It's seen as good for equities.

Pre 2000

Intercept	Ycor	EXPINF_S	EXPINF_L	UNINF_S	UNINF_SIGMA
0.0101	0.372 ***	271.29 *			
0.0005	0.346 ***		0.100 *		
0.3861	0.393 ***			-104.7	
0.3726	0.397 ***				18.31
0.124	0.337 ***		0.114 *		-268.4

Post 2000

Intercept	Ycor	EXPINF_S	EXPINF_L	UNINF_S	UNINF_SIGMA
-0.1873	0.432 ***	17.283			
-0.1331	0.445 ***		-0.023		
-0.1707	0.444 ***			-0.312	
-0.1832	0.444 ***				8.9369
-0.261	0.326 ***		-0.029		24.149

Source: UBS

## Section 2

# Return decomposition

# Return decomposition

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- What drives stock returns? If we consider a discounted cash flow model (of any sort) then a change in the price must be down to either
  - A change in the top line, the cash flows, or
  - A change in the bottom line, the discount rates.
- In order to derive the model we start with an approximation from Campbell and Schiller (1988) where they approximate the log return on a dividend paying asset  $r_{t+1} = \log(P_{t+1} + D_{t+1}) - \log(P_t)$  using a Taylor series expansion around the long term mean log dividend-price ratio  $\overline{(d_t - p_t)}$  where  $P$  and  $D$  are the price and dividend and  $p$  and  $d$  are their logs.

- The approximation is

$$r_{t+1} \approx k + \rho p_{t+1} + (1 - \rho)d_{t+1} - p_t$$

- where  $\rho = 1 / (1 + \exp(\overline{d_t - p_t})) \approx 0.96$  and  $k = -\log(\rho) - (1 - \rho)\log(1/\rho - 1)$ .

# Return decomposition (2)

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- Campbell (1991) took this idea and provided the following (approximate) decomposition of unexpected returns

$$\begin{aligned} e_{t+1} &= r_{t+1} - E_t r_{t+1} \\ &= (E_{t+1} - E_r) \sum_{j=0}^{\infty} \rho^j \Delta d_{t+1+j} - (E_{t+1} - E_r) \sum_{j=0}^{\infty} \rho^j r_{t+1+j} \\ &= e_{CF,t+1} - e_{DR,t+1} \end{aligned}$$

where  $r_{t+1}$  is the equity return and  $E_t$  is the expectation at time  $t$ .  $\rho$  is the constant from above, and  $\Delta d_t$  is the dividend growth rate.  $e_t$  is the unexpected market return, and  $e_{CF,t}$  and  $e_{DR,t}$  are its cash flow and discount rate news components.

- So unexpected returns are a function of changes in expectation about future dividends ("cash flow news") and changes in future expected returns ("discount rate news").

# Fitting the model

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- How do we fit the model? The (usual) approach (from Campbell and Vuolteenaho (2004)) is to model the discount rate news and then calculate the cash flow news as the residual.
- The discount rate  $r_t$  is modelled as part of a VAR model
- $z_{t+1} = a + \Gamma z_r + u_{t+1}$
- Where it has become convention to put  $r_t$  as the first element in  $z_t$  and the other variables are chosen as ones that have some predictive power for  $r_t$ . In the 2004 paper they use the term spread, the 10 year PE and the small stock value spread.
- Chen & Zhao (2009) have some criticisms of this approach (saying it is somewhat unstable as any modelling errors get pushed into the cash flow news) but Engsted et al (2010) provide a reasonable defence of the approach.

# Fitting the model (2)

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- Once we have fitted the VAR model then it follows that

$$\begin{aligned} -e_{DR,t+1} &= -(E_{t+1} - E_r) \sum_{j=0}^{\infty} \rho^j r_{t+1+j} \\ &= e1' \sum_{j=0}^{\infty} \rho^j \Gamma u_{t+1} \end{aligned}$$

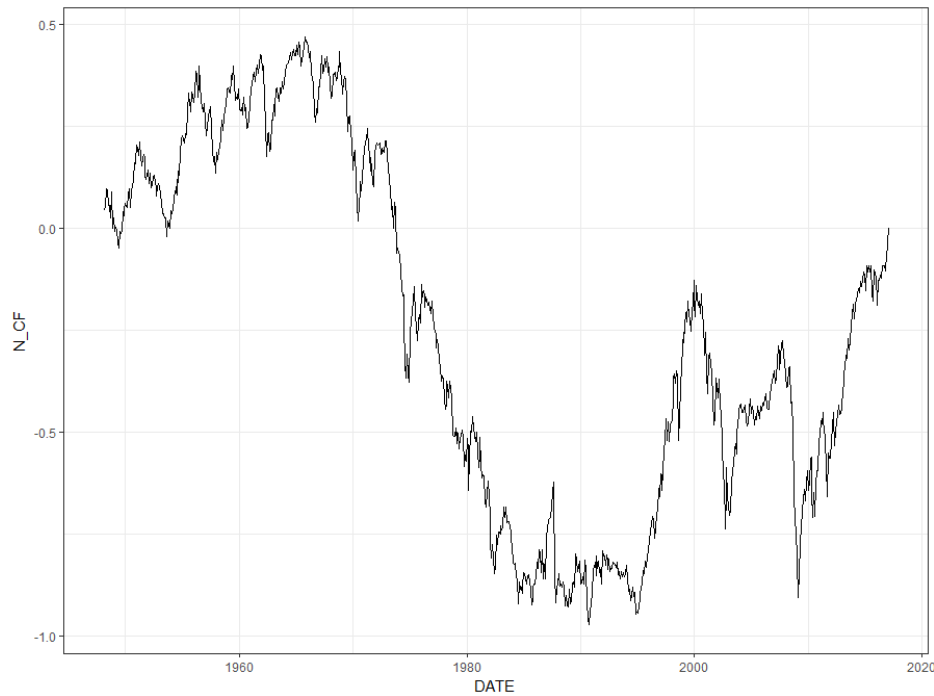
$$= e1' \rho \Gamma (I - \rho \Gamma)^{-1} u_{t+1} = e1' \lambda u_{t+1}$$

- where  $\lambda = \rho \Gamma (I - \rho \Gamma)^{-1}$  and  $e1$  is a vector where the first element is 1 and the rest are zero.
- And then the cash flow news is simply  $(e1' + e1' \lambda) u_{t+1}$

# Picture of cash flow and discount rate news

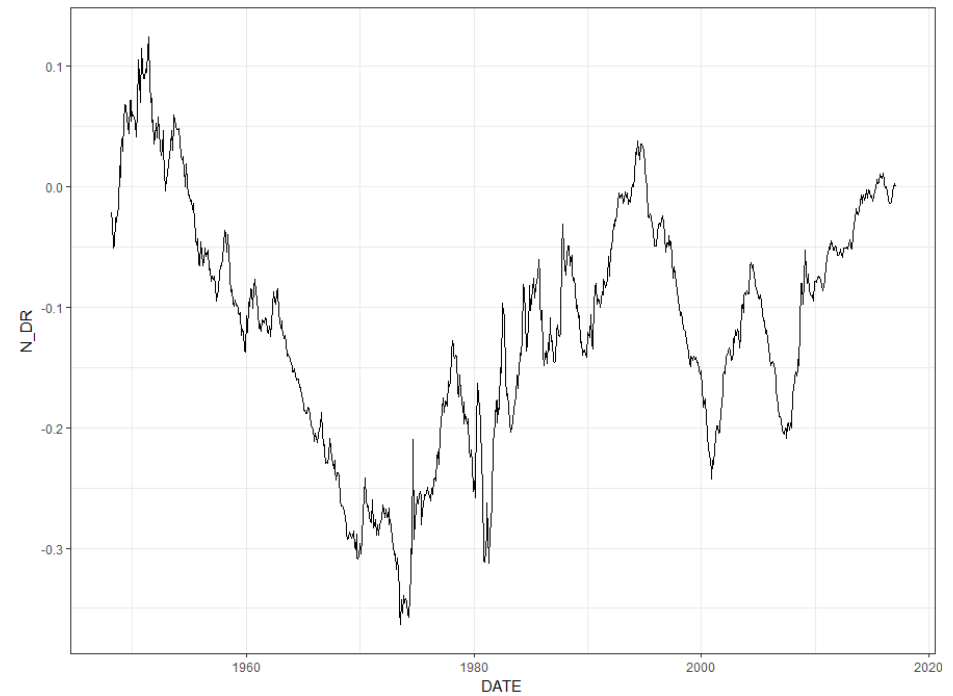
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## Cash flow news



Source: UBS

## Discount rate news



Source: UBS

# Relationship with inflation over time

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- Historically (pre 2000) the correlation of inflation with discount rate news and cash flow news was negative (-0.40 and -0.19 respectively).
- Since 2000 the correlation with discount rate news has remained negative but smaller (-0.16) and the correlation with cash flow news has turned positive (0.07) – so again backing up the idea that increasing inflation is now seen as a positive thing



# Conclusions

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- Since 2000 stock-bond correlations have been negative, in contrast to the previous 200 years.
- The main driving force behind this change seems to be the influence of inflation on equity returns – higher inflation is now apparently good news for equities.
- The flight to quality effect seems to have grown larger – the correlation falls more when the VIX increases.

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<b>Neutral</b>	FSR is between -6% and 6% of the MRA.	39%	27%
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<b>Buy</b>	Stock price expected to rise within three months from the time the rating was assigned because of a specific catalyst or event.	<1%	<1%
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