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The FED model: Is it still with us?

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ABSTRACT

The Fed model, a stable relation between equity and bond yields, with accompanying predictive power for subsequent stocks returns has proved a controversial idea within empirical finance. This paper re-examines the equity-bond yield relation and its predictive power in the light of potential breaks or level-shifts. We argue that while a positive relation exists between the two yields it does not fluctuate around a single stable point. Notably, we demonstrate switching behaviour between high and low values of the Fed series, which correspond inversely to movements in the real interest rate and is linked to observed changes in the inflation-growth relation. Accounting for such shifts leads to an improvement in relative predictive power over a set of baseline models, including a linear, non-regime varying, approach. This occurs both in terms of point prediction and directional accuracy, including crash prediction. We also provide evidence in favour of bond return predictability, although predominantly at longer-horizons. The results here reveal that the equity and bond yield interaction is informative for investors, but only when accounting for shifts in behaviour.

1. Introduction

Empirical finance has a troubled relation with the interaction between equity and bond yields. As part of a diversified portfolio, investors would hold both assets but may overweigh towards one should it offer a (temporary) higher yield. This leads to a positive correlation between equity and bond yields, with a view that the relative yields act as a trading signal and fluctuate around a fixed point. Notably, the relation between the two yields is often portrayed in terms of its ratio or as the yield gap (difference), and this is typically referred to as the Fed model or Fed ratio.[1] Regardless of the way in which it is expressed, however, the relation is expected be a stationary one, where investors move between assets should the yield ratio or difference move such that they can take advantage of a higher yield for one asset, leading to a reversal of the initial move. For example, should the yield on equity be higher, investors will buy stocks, increasing their price and reducing the yield at the same time as selling bonds, reducing their price and increasing the yield. This mechanism, where the assets compete against each other, should also give rise to a predictive relation for asset returns i.e., a higher equity yield relative to the bond yield predicts higher future stock returns (see, for example, Bekaert & Engstrom, 2010; Maio, 2013; Lleo & Ziemba, 2015, 2017; Humpe & McMillan, 2018).

The idea of a stationary relation between equity and bond yields and of predictive power arising from the Fed model is not without controversy, both theoretical and empirical. The main theoretical objection is in terms of the mixing between real and nominal assets, and this has been well espoused by Asness (2003) and Estrada (2009). Although this argument is often countered with the idea of

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[1] As discussed in Section 2, there are three approaches to the construction of the relation between the equity and bond yields. For simplicity, we will refer to all of these as the Fed model and denote them numerically below.

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money illusion whereby investors discount cashflows by the nominal rather than real rate (see, for example, Campbell & Vuolteenaho, 2004; Cohen et al., 2005). Moreover, Thomas and Zhang (2008) and Bekaert and Engstrom (2010) provide arguments in favour of the consistency of the Fed model even without appealing to irrationality.

Empirical research is similarly mixed with the above cited literature, among others, providing equal amounts of supportive and opposing evidence. For example, Asness (2003) and Estrada (2009) argue that any predictive relation only arises in short time periods given the lack of rigour in the underlying relation, while Bekaert and Engstrom (2010) find supportive evidence for a range of markets and Maio (2013) provides evidence of its success in forecasting US stock returns. In a different tact, Koivu et al. (2005), Estrada (2006, 2009) and Zakamulin and Hunnes (2022) consider the underlying cointegrating relation, including the potential for breaks. Humpe and McMillan (2018) argue that the relation is inherently non-linear, which may in turn explain the time-varying nature of the evidence.

A related literature demonstrates that, undoubtedly, the relation between equity and bond yields is a dynamic one that is prone to shifts. To illustrate this, for the US data used throughout this study, Fig. 1 shows that while between 1980 and the early 2000s the bond yield is greater than the equity yield, this is not true prior to 1980 and after approximately 2005, and especially after 2010. Asness (2000) argues that the relative value of the equity and bond yield depends on the relatively volatility of the two assets. A question that arises is what this means for the existence of a stationary relation between the equity and bond yields and for any predictive power that may reside therein. In a related but separate literature, several papers have identified breaks and time-variation within a different set of stock market related variables, see, for example, Paye and Timmermann (2006), Lettau and van Nieuwerburgh (2008), Hammerschmid and Lohre (2018) and Baltas and Karyampas (2018).

This paper seeks to consider whether the Fed relation (still) exists in a period that is characterised by inflation and interest rates that have fallen from the highs of the late 1970s/early 1980s, to a more stable period in the 1990s and early 2000s, through quantitative easing since the financial crisis that has pushed bond yields to historic lows (as observed in Fig. 1) and then a rise in yields following the invasion of Ukraine by Russia, leading to an energy price and inflation spike. Notably, after examining the behaviour of the Fed series (calculated in three different ways) and both standard predictive and directional accuracy regressions for subsequent stock returns, we consider the potentiality of the Fed series to exhibit breaks/level-shifts or regimes of behaviour. Given the observations in Fig. 1, breaks may occur around switches in the relative values of the equity and bonds yields as well as following the financial crisis and the introduction of quantitative easing. Accounting for the presence of breaks may reveal predictive power that otherwise remains

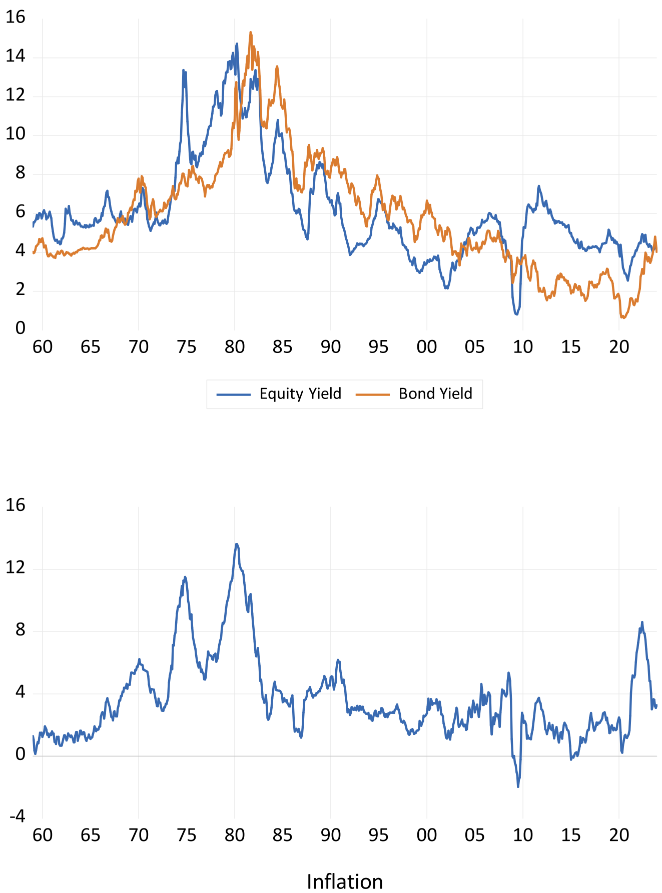

Fig. 1. Equity yield, bond yield and inflation.

uncovered when considering the full-sample period and thus, be of interest to investors in building portfolios. Further, in seeking to understand the cause of any identified breaks by linking them to explicit variables, this will be of interest to those engage in modelling market behaviour.

In contributing to the literature, our results show that only when accounting for breaks in the Fed relation is consistent evidence of predictability uncovered. Using the unadjusted Fed series leads to limited evidence, which is potentially ascribed to non-stationary behaviour. Thus, there is a need to account for such breaks to ensure robust and reliable results. Albeit in a different econometric context, this provides some consistency with the work of Zakamulin and Hunnes (2022), but more generally provides a resolution to the conflicting evidence reported in the literature. In addition, this paper contributes by seeking to identify the factors that drive the break rather than only identify the existence of a break, which is more common in previous work. Notably, the break is primarily driven by shifts in monetary policy regimes captured by the real interest rate, while the effect of the changing inflation-growth correlation also plays role. These results will help our understanding of market behaviour.

2. Background

The basic idea of the Fed model is that there exists a positive relation between equity and bond yields, and this can be observed within Fig. 1; a discussion of the how the term 'Fed model' came into being is noted in Asness (2003) and Maio (2013), among others. The Fed model is presented in different ways, typically as a ratio of the equity to bond yield, but also as the difference between the two yields (often referred to as the yield gap, which may also be in log form). Regardless of the specific presentation of the model, the underlying idea is the same, that the ratio or gap will be stable (i.e., stationary). This arises as the two asset types compete for investor funds, who seek to take advantage of any discrepancy in the respective yields. As such, a high equity yield (higher earnings relative to stock price) will see investors sell bonds to buy stocks and thus causing the yields to converge as that on the former rises (price falls), while reducing on the latter (price increases). Thus, the basic idea behind the Fed model is:

$$(E_t/P_t) = Y_t \tag{1}$$

where E_t / P_t is the earnings-to-price ratio of a market index and Y_t is the bond yield of a longer-term bond, typically 10-year. As noted, it is the behaviour of investors who maintain this ratio, or, at least, ensure a strong correlation between the two yields. Therefore, the ratio should fluctuate around one or the yield gap (yield difference) around zero. More generally, however, as we typically argue that stocks are riskier than bonds, then we would expect a higher equity yield to reflect a required premium i.e., $(E_t /P_t) = RP_t \, x \, Y_t$ or $(E_t /P_t) – Y_t > 0$ (where RP_t refers to a risk premium).

As argued by Asness (2003), among others, the equity yield relates to real variables (expected real cashflows and discount rates), while the bond yield depends on nominal variables (notably, expected inflation). Given that a nominal variable (expected inflation) should not affect a real variable (cashflow and discount rates), then the two yields should not be related, and the Fed model would not translate into a stable relation (i.e., any favourable evidence would be the result of a fortunate sample period).

In defence of the presence of a positive relation between the two yields, one explanation arises from money illusion, i.e., that investors discount using nominal rather than real rates such that inflation affects both yields (Modigliani & Cohn, 1979; Campbell & Vuolteenaho, 2004; Ritter & Warr, 2002). In contrast, Sharpe (2001) argues that high inflation masks the signal arising from fundamentals, while lower inflation leads to more accurate valuations, a lower required rate of return, higher expected earnings growth, and higher stock prices. As such, a lower equity yield accompanies lower inflation and bond yield as a reflection of the more stable economic conditions.

However, rational explanations for the positive relation between the equity and bond yield are also suggested. In the discussion provided by Bekaert and Engstrom (2010), they argue that the equity yield exhibits a positive correlation with inflation expectations (and thus, the bond yield) due to variation in the rational time-varying risk premium. Specifically, and using the present value model (Gordon, 1959) as a base, the equity yield depends on expected growth and an equity risk premium, while the bond yield depends on inflation, both expected and as a risk premium (both yields also depend on the risk-free rate). Thus, and also following Schwartz and Ziemba (2000) and Lleo and Ziemba (2015), we can argue that the difference, $(E_t /P_t) – Y_t$, depends on the equity premium, expected growth and inflation. A higher inflation rate will increase the bond yield and the equity risk premium. This, in turn, arises from economic uncertainty as a result of inflation, which itself, in turn, is further related to the arguments of Fama (1981) whereby higher inflation, leads to falling stock prices due to poorer expected economic conditions.

Maio (2013) also argues in favour of a stable relation between equity and bond yields. Using the general approach of Campbell and Shiller (1988), Maio (2013) notes that the difference between the two yields depends on expected values of the stock return, dividend/ price ratio, earnings growth rates and interest rates. Thus, capturing the same effect as the above noted work, i.e., the equity risk premium and inflation (which will influence the expected interest rates).

In understanding the Fed model, the relation between equity and bonds yield and the predictive power for stock returns, we can consider several, related, approaches. Before considering any underlying theoretical relations, we can argue that an empirical cointegrating relation exists between equity and bond yields. From Fig. 1 non-stationary behaviour within each yield can be observed, with a similar long-run pattern, suggestive of cointegration. The Fed model, therefore, essentially captures the error-correction term. To consider underlying theoretical reasons for the Fed model, a place to start is the no-growth dividend discount model:

$$P_t = D_t/R_t \tag{2}$$

where the stock price, P_t, depends on dividends, D_t, and the required rate of return, R_t. While there is no single approach to determining

R_t, it is generally believed to consist of a safer asset, such as Y_t and a risk premium, i.e., $R_t = Y_t + RP_t$. Assuming that all earnings, E_t, are paid out in dividends and that there is no risk premium, then equation (2) is rewritten as equation (1).

This simple relation can be made increasingly complex. For example, we can introduce growth into the above relation between equity and bond yields. Here, the stock price depends on future dividends, D, the required rate of return, R, and the growth rate, g:

$$P_t = D_t(1+g_t)/(R_t - g_t) = D_{t+1}/(R_t - g_t). \tag{3}$$

Where we allow b to represent the (constant) payout ratio (i.e., $b = D/E$) and where the return on new investments (R^*) is identical to existing ones (R), equation (3) can be rewritten as:

$$P_t = bE_{t+1}/(R_t - (1-b)R_t^*) = P_t = E_t^f/R_t \tag{4}$$

where we have substituted expected earnings, E_{t+1}, with E_t^f to represent one-period ahead forward-looking earnings. This again, leads us back to the initial relation in equation (1).

Taking this a further step, we can then tie the Fed model with the Campbell and Shiller (1988) version of the dividend discount model. This is the approach taken in Maio (2013) and so is only briefly stated to avoid repeating the discussion, and notably with the accompanying appendix therein. Following Campbell and Shiller (1988), who allow for a time-varying discount rate, the log dividend-price ratio is given as[2]:

$$d_t - p_t = \frac{-\kappa}{(1-\rho)} + E_t \sum_{i=0}^{\infty} \rho^i (r_{t+1+i} - \Delta d_{t+1\_i}) \tag{5}$$

where κ and ρ are linearisation parameters. Maio (2013) incorporates first, the dividend payout ratio to express the relation in terms of earnings and second, the expectations hypothesis of interest rates to include the long-term yield, arriving at:

$$(e_t - p_t) - y_t = \frac{-\kappa}{(1-\rho)} + E_t \sum_{i=0}^{\infty} \rho^i \left(r^e_{t+1+i} - (1-\rho)(d_{t+1+i} - e_{t+1+i}) - \Delta e_{t+1+i} \right) + E_t \sum_{i=n}^{\infty} \rho^i r_{f,t+1+i} \tag{6}$$

This equation, therefore, relates the Fed model to future (excess) returns, r_t^e, dividend payout ratio, $d_t - e_t$, earnings growth, Δe_t, and short-term (risk-free) interest rates, $r_{f,t}$.

As noted above, empirical evidence for the Fed model and its predictive power for stock returns is mixed. In debating the theoretical validity of the model, Asness (2003) on the one hand argues against predictive power, while Bekaert and Engstrom (2010) and Maio (2013), on the other, present supportive evidence. There also exists an older literature that refers to the B(G)EYR (bond (gilt) equity yield ratio), which additionally presents supportive evidence (see, for example, Clare et al., 1994; Levin & Wright, 1998; Harris, 2000; Brooks & Persand, 2001; McMillan, 2009, 2012). Regarding more recent evidence, Zakamulin and Hunnes (2022) consider the underlying cointegrating vector between *(E/P)* and *Y* (if the Fed model is a stationary relation, then the constitute parts must form a cointegrating set, or both also be stationary). Zakamulin and Hunnes argue that cointegration is only found in part of the sample and that the magnitude of the cointegrating parameter that links the two series changes over time. In a different tact, Humpe and McMillan (2018) examine the nature of the correlation between the two yield series and suggest that a non-linear relation exists.

These latter two papers suggest that changes, and time-variation, exist in the nature of the equity and bond yield relation and this in turn would support the reported mixed evidence. This paper re-examines the relation in the light of the shift in the relative position of the equity and bond yields that can be observed in Fig. 1. Specifically, the bond yield is greater than the equity yield over the approximate 25-year period from 1980 to 2005, while this position is reversed both before 1980 and (especially) after the financial crisis.

3. Data and Fed model Characteristics

Monthly US data for the S&P Composite index and earnings, and 10-year and 3-month Treasury yields are obtained over the sample period from 1959M1 to 2023M12.[3] The data is obtained from the website of Shiller and the St Louis Federal Reserve FRED database. As noted above, the Fed ratio can be constructed in different ways and Fig. 2 presents these three versions. Table 1 presents the summary statistics of the data, including the three Fed series as well as stock returns and both the earnings-to-price ratio and the term structure (10-year minus 3-month Treasuries) that are used in the regression analysis.

In the succeeding discussion, we refer to these as Fed1 (the ratio of the equity yield to bond yield), Fed2 (the different between the equity yield and the bond yield) and Fed3 (the log version of Fed2, used in the work of Maio, 2013). More specifically, these can be specified as:

$$Fed1 = (E_t/P_t)/Y_t \tag{7}$$

where E_t refers to the S&P Composite earnings index, P_t is the S&P composite price index and Y_t is the 10-year Treasury bond yield. This

[2] Following convention, the lower-case letters refer to the natural log of the variable.
[3] This, therefore, gives us 756 observations.

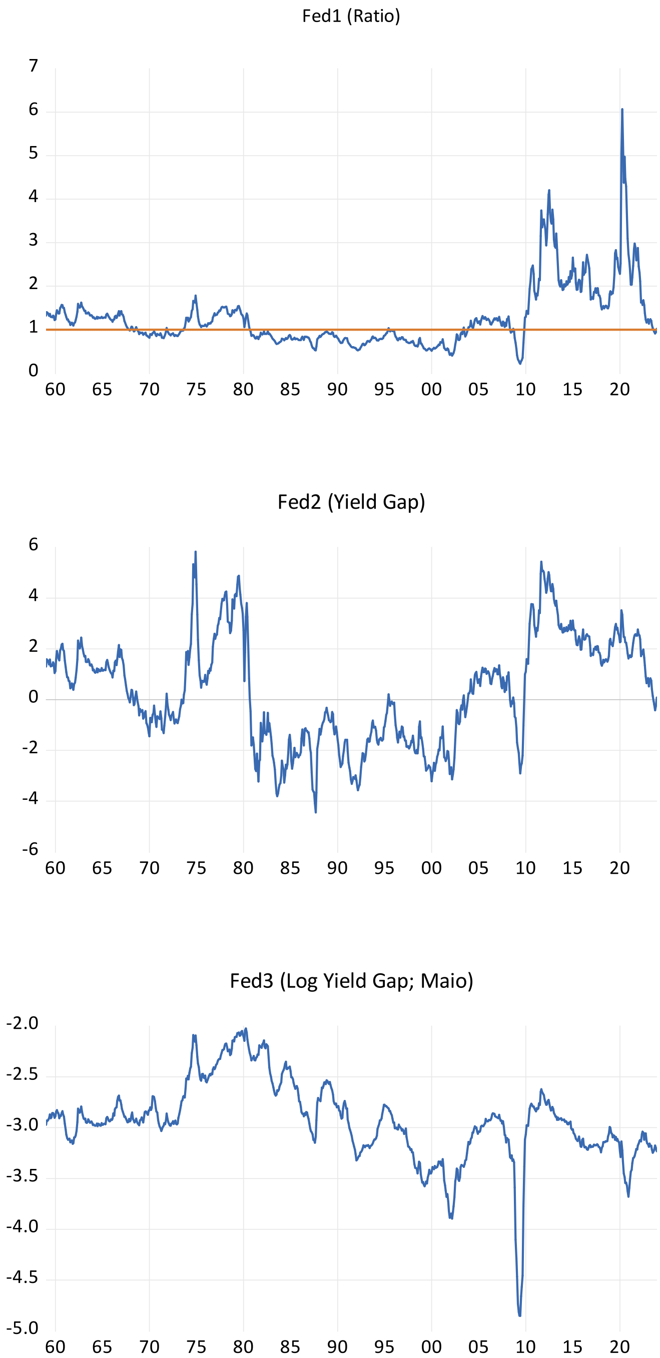

Fig. 2. Fed series.

is a common approach for the Fed model expression and often used to highlight periods of over- and under-valuation.[4] An alternative specification, popularised in the yield spread literature (e.g., Lleo & Ziemba, 2015, 2017) as well as considered within Asness (2003), is:

$$Fed2 = (E_t/P_t) - Y_t \tag{8}$$

this approach is also used by Maio (2013) in one of their robustness tests, however, their main approach is to consider the log-version:

[4] This is approach is often popularised by finance houses (see, for example, Yardeni.com).

Table 1
Descriptive statistics.

Series	Mean	Std Dev	Min	Max	Skew	Kurt	JB	DF-GLS
Returns	0.573	3.585	–22.80	11.35	−1.215	8.039	0.00	−5.44
Fed1	1.267	0.723	0.218	6.069	2.314	10.551	0.00	−3.24
Fed2	0.337	2.090	−4.444	5.825	0.129	2.232	0.00	−2.53
Fed3	−2.932	0.401	−4.851	−2.024	−0.614	6.095	0.00	−3.99
EP	6.130	2.592	0.808	14.728	1.213	4.244	0.00	−2.16
TS	1.438	1.222	−2.650	4.420	−0.221	2.696	0.01	−4.45

Notes: The entries are the mean, standard deviation, skewness, and kurtosis values for the monthly stock return, the three Fed model series, the earnings-to-price rate and the term structure (10-year minus 3-month Treasuries). In addition, the Jarque-Bera normality test p-value and the DF-GLS unit root tests are also reported. The critical value for the DF-GLS test is −1.94.

$$Fed3 = log(E_t) - log(P_t) - log(1 + Y_t) = e_t - p_t - y_t \tag{9}$$

In confirming the Fed model series construction, we can compare the Fed2 and Fed3 graphs in Fig. 2 here, with those in Fig. 1, Panels A and C, of Maio (2013).

Examining the graphs for these different Fed model series, we can observe some commonality within their movements together with notable differences. We can see that for Fed1 (yield ratio), the series does fluctuate around the value of one for much of the sample period. However, this series then moves to a higher level, fluctuating around two, after the financial crisis but with some large deviations therefrom and some indication of a return to the value of one following the high inflation period of 2022. For Fed2 (the yield gap), the series fluctuates around zero but is predominately above this value prior to 1980 and after 2010 and below in the intervening period (consistent with the pattern in Fig. 1). Again, in the most recent period, we see the series returning to its 'equilibrium' value of zero. For Fed3 (log yield gap), we see a similar pattern as with Fed2, although there is no noticeable increase in the series towards the end of the sample as is seen with both Fed1 and Fed2, while the effect of the financial crisis is magnified.

Within each of the three graphs we can observe that the values of the Fed series are higher over the first part of the sample and especially the late 1970s. They are then lower during the 1980s, 1990s and the 2000s, before rising in the post-financial crisis period, with some evidence of a decline in the high inflation and increasing interest rate period from 2022, following the invasion of Ukraine by Russia. As observed in Fig. 1, the period associated with the late 1970s is one with higher inflation and while inflation did begin to increase prior to the financial crisis, it was subdued thereafter, although, it did rise notably in 2022. Thus, in seeking to understand the dynamics of the Fed model series, inflation may only be part of that explanation as increases in the Fed series is not wholly associated with higher inflation.

As discussed above, where the Fed model is a feature of market behaviour, then it should exhibit a stationary relation. The three Fed graphs do indicate a tendency for the series to fluctuate around a fixed mean, although perhaps only weakly for Fed2 and Fed3, while a clear jump is observed for Fed1. As part of the summary statistics in Table 1, unit root tests are presented. These tests do confirm stationarity for each series, although the graphical evidence (especially for Fed1) is less convincing, while the AR(1) coefficient for each series is 0.98 or above. Stationarity is also reported for the other series, which also all exhibit non-normality.

4. Predictability and breaks

This section looks at the question of predictability arising from the Fed model series, including the potential for breaks within the nature of the data. This begins with the standard predictive regression, before considering the potential for breaks within the Fed model series, which are suggested in the dynamics presented in Fig. 2. As well as examining whether break adjusted Fed series improves predictability, this section also looks to provide an explanation for the breaks, including around changes in macroeconomic regimes. While research typically focuses on stock return predictability, we also consider that for bond returns.

4.1. Predictability I

As noted in the Introduction, there is a line of research that highlights predictive power for stock returns arising from the Fed model series. This potential predictive power proves controversial from both theoretical and empirical perspectives. As discussed in Section 2, the theoretical argument against predictability is that bond and equity yields represent nominal and real variables respectively and thus, should not exhibit a relation, while both rational and irrational based models are advanced in support of a predictive relation. The empirical evidence is mixed, with results that both do and do not support predictive power. We re-examine the nature of the empirical evidence and consider the ability of the three Fed model variations to predict subsequent stock returns.

Table 2 reports the results of the predictive regression:

$$r_{t+k} = \alpha + \beta_1 Fed_t + \Sigma_i \delta_i x_{i,t} + \varepsilon_{t+k} \tag{10}$$

where r_{t+k} represents the subsequent stock return over the k-horizon, *Fed* refers to the Fed model (where we estimate the regression for each of the three variants), x_t are controls variables typically used in stock return predictability, namely the earning-to-price ratio and the term structure (10-year minus 3-month Treasury yields), and ε_t is a white noise error term. In seeking to examine predictive power,

Table 2
Predictive regressions – Original fed series.

Series	No Fed	Fed1		Fed2		Fed3	
	K = 1						
Fed		0.467[a]	0.508[a]	0.109	0.129[c]	0.185	−0.208
		(2.86)	(2.98)	(1.50)	(1.82)	(0.36)	(−0.14)
EP	0.051		0.057		0.030		0.080
	(0.75)		(0.85)		(0.45)		(0.40)
TS	0.174		0.207		0.217		0.172
	(1.28)		(1.53)		(1.60)		(1.29)
Adj-R2	0.002	0.008	0.011	0.003	0.005	−0.001	0.001
	K = 3						
Fed		1.311[a]	1.426[a]	0.300	0.333[c]	0.682	−1.857
		(2.79)	(2.89)	(1.48)	(1.69)	(0.46)	(−0.47)
EP	0.192		0.210		0.138		0.459
	(1.02)		(1.12)		(0.74)		(0.83)
TS	0.441		0.536		0.553		0.420
	(1.21)		(1.49)		(1.53)		(1.18)
Adj-R2	0.007	0.017	0.026	0.007	0.014	0.000	0.007
	K = 12						
Fed		3.682[b]	4.309[a]	0.768	0.884	3.867	−5.305
		(2.50)	(2.68)	(1.46)	(1.60)	(0.99)	(−0.56)
EP	1.000[b]		1.063[b]		0.860[c]		1.761
	(2.02)		(2.18)		(1.71)		(1.36)
TS	2.470[b]		2.792[a]		2.776[a]		2.407[b]
	(2.32)		(2.73)		(2.59)		(2.28)
Adj-R2	0.052	0.030	0.092	0.010	0.064	0.009	0.052

Notes: Entries are the coefficients, Newey-West *t*-statistics and Adjusted R-squared value for equation (10). The Fed model series are the original series, as observed in Fig. 2. The superscript letters ‘a’, ‘b’, and ‘c’ refers to 1%, 5%, and 10% significance respectively.

equation (10) is estimated both including and excluding the control variables, while we consider horizons $k = 1, 3, 12$ (i.e., one-month, one-quarter, one-year). As a baseline, we also include a variant of equation (10) excluding the Fed model series.

In examining the estimated results in Table 2, across the different Fed model variants and three time-horizons, we observe mixed evidence in favour of predictability arising from the Fed model. For the Fed1 series (the ratio of the equity to bond yield), there is a positive and significant relation for each horizon and when including and excluding the additional control, variables. For Fed2 (the yield difference or gap), there is also a positive relation, however, this is only significant at the 10 % level, where it is significant. This being the horizons of $k = 1$ and 3 when including the control variables. For the Fed3 series (the log yield gap), this coefficient is insignificant throughout and even negative when including the control variables. Thus, only partial supportive evidence is gained towards Fed model predictive power. Moreover, as observed in Fig. 2, the Fed1 series does appear to exhibit non-stationary behaviour, which casts further doubt on the robustness of this result. At best, and predominantly using the results of the Fed2 series, we can argue only for weak predictive evidence from the Fed model. For the control variables, the term structure shows evidence of increasing predictive power with the horizon, while the earnings-to-price ratio is largely insignificant, but with some exceptions.

4.2. Breaks

The above results, and the lack of consistent evidence in favour of predictive power arising from the Fed model could occur either because no such consistent predictive power exists or due to regime changes (or level-breaks). In considering Fig. 2, we can observe the potential for breaks, or level-shifts, within the mean of the Fed series. This is clearly apparent with the Fed1 series, where a step change in most noticeable towards the end of the sample period (visually, this appears to be approximately in 2010). This is consistent with the period of quantitative easing, which kept interest rates historically low. Further potential breaks are also noticeable across the sample, including toward the end of the 1970s / early 1980s and the early 2000s. This former period would be associated with heighted inflation (and subsequently interest rates) arising from the OPEC oil price shocks and the more subdued inflation during the 1980s. The latter period is associate with bursting of the dotcom bubble and the lower interest rates that followed.

To consider the presence of breaks, we follow the approach of Bai and Perron (1998, 2003a,b) by regressing each of the Fed series on a constant term and testing for a break in its value.[5] The use of breakpoint tests is considered in the related work of Paye and Timmermann (2006), Lettau and van Nieuwerburgh (2007), and, more recently, Xuan and Kim (2020) in considering price ratio predictability for stock returns. Table 3 reports the formal results of the breakpoint tests, while the breaks are noted within Fig. 3, which also presents the de-meaned series. Across the three Fed series, we observe some consistency in the number of breakpoints and the estimated dates, although with some differences. Of note, the Fed series are lower during the 1980s and 1990s (for Fed3, this occurs only in the 1990s) than at the start and end of the sample period. As noted in Fig. 1 that includes the annual inflation rate, we observe a

[5] In brief, we estimate: $Fed_t = \alpha_s + \varepsilon_t$, where the subscript s denotes the shifts or regimes that are determined by the breakpoint tests or, subsequently, the Markov-switching approach.

Table 3
Bai-Perron breakpoint tests.

Break	Fed1	Fed2	Fed3	EP	TS
0 vs 1	65.11*	88.32*	74.89*	71.41*	19.99*
1 vs 2	75.48*	81.25*	74.60*	68.15*	13.68*
2 vs 3	5.57	18.99*	17.42*	3.36	5.52
3 vs 4		3.55	9.39		
Break Dates	1980:09; 2010:05	1980:10; 2000:05; 2010:02	1973:11; 1991:01; 2009:12	1973:11; 1991:02	1981:10; 2014:04

Notes: Entries are the test statistics (F-test) from the Bai and Perron breakpoint tests, where the asterisk denotes 5% (or above) statistical significance based on Bai and Perron (2003b).

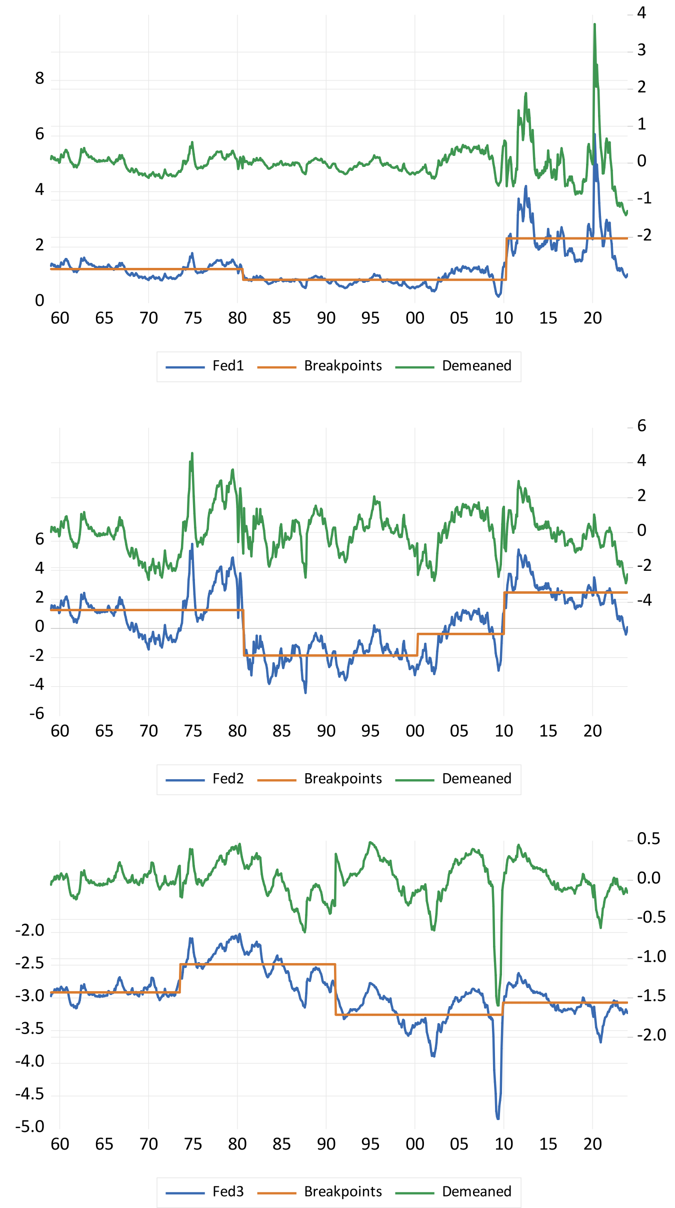

Fig. 3. Fed series breakpoints.

substantial fall in inflation during the early 1980s, which is consistent with the break in the Fed series. These breakpoints are also consistent with the relative values of the equity and bond yields noted in Fig. 1. That is, prior to approximately 1980, the equity yield was higher than the bond yield and is likewise again after 2010 (and, to an extent, after approximately 2003). A key question is understanding the implications of these breaks for predictability.

From a modelling perspective and for an investor seeking to use information in the Fed model to predict subsequent stock returns, there are limitations to the structural break approach. Notably, breakpoints can only be determined ex-post, and this creates difficulty when considering forecasting. In seeking to capture the same information, we utilise the Markov-switching model of Hamilton (1989). As with the Bai-Perron approach, in this model, we estimate the Fed model against a constant, which is allowed to vary across regimes of behaviour. Allowing for two regimes, this identifies high and low Fed model values and can capture information akin to the breakpoints in the previous analysis.[6]

Fig. 4 presents the smoothed regime probability results, allowing for two regimes.[7] For clarity in the graph, we present the results only for the Fed2, yield gap, series and include in the plot both the series itself and the Bai and Perron breakpoints for comparison. Here we can see a high degree of commonality between the identified regimes in the Markov-switching model and the Bai-Perron breakpoints, although the former model does capture some additional dynamics. Notably, the Markov-switching model identifies a switch from a high to low regime at the end of the 1960s and back to a high regime in the mid-1970s. As with the Bai-Perron test, we see a regime switch at the beginning of the 1980s, with the Fed model remaining in the lower regime until 2003. The Fed series then remains in the high regime, with the exception of a short period between late 2008–2009, for the remainder of the sample period, with some evidence of a move back to the low regime at the end of the sample.[8]

4.3. Predictability II

The previous lack of consistent evidence in favour of predictive power could arise from the regime changes (level-breaks) identified in Figs. 3 and 4. To consider this question, Tables 4 and 5 repeat the above predictive regression but the original Fed model variable is replaced by two versions of an adjusted Fed variable. The first adjustment is obtained by subtracting the Bai and Perron breakpoint mean value from the Fed ratio. The second adjustment does likewise for the Markov-switching regime-varying mean (in essence, we obtain the residual from the estimated switching models). In application of the breakpoint regressions (Table 4), we initially allow the Fed model series to vary according to the identified breakpoints but hold the control variables (the earnings-to-price ratio and term structure) to a fixed mean. However, as noted in Table 2, breaks also occur in these series, such that the third column of results for each of the Fed series also allows for breaks in these variables. For the Markov-switching results (Table 5), all variables are allowed to switch.

Looking across both Tables 4 and 5, we can see a high degree of consistency in the results. For the Fed1 and Fed2 adjusted series, both breakpoint and Markov-switching adjusted, the coefficient is positive and significant at all horizons, both with and without the control variables. The Fed3 adjusted variable, however, continues to be statistically insignificant. For the control variables, when holding to a constant mean, we continue to see evidence of a positive and significant effect from the term-structure at the one-year horizon. However, when allowing for breaks in these variables (Table 4), there is greater evidence of predictive power arising from the earnings-to-price ratio. Nonetheless, this added flexibility does not affect the nature of the Fed model results. In comparing the alternative Fed model series, we can consider the (adjusted) R-squared values obtained from each of the regressions, across both the original and adjusted series. When considering the original Fed model series, the Fed1 variable obtains the highest R-squared values, while for the adjusted series, the Fed2 variant has the highest values across the two tables. Overall, the adjusted R-squared is highest for the breakpoint adjusted Fed2 at the monthly and annual horizons, while at the quarterly horizon, the Markov-switching Fed2 achieves the highest value, although the differences between the two models at this horizon is small.[9]

The above results support a positive relation between the Fed model series and subsequent stock returns, with statistical significance that is enhanced once we account for level-shifts. This implies that a higher equity yield (and thus, a lower stock price relative to earnings) to bond yield predicts an increase in future returns. This is consistent with the view that a higher equity yield will result in investors moving from bonds to equities and so increasing the future stock price. In addition, a high equity-to-price ratio acts as a signal for higher future returns. This follows the work of Campbell and Shiller (1988) and Fama and French (1988), who argue that a higher cashflow- (earnings or dividend) to-price ratio predicts higher subsequent returns as the higher ratio signals improving economic conditions (higher cashflow) or increased risk (lower current prices and higher resulting returns). Conversely, an increase in the bond yield, would lead to a fall in the Fed model series and a decrease in future stock return as investors move from stocks to bonds, lowering the stock price.

[6] In application of the Markov-switching model, regimes switching is allowed for both the constant and error-variance. Two regimes were allowed for, while experiment with a third regime led to a failure to converge for the Fed2 series.

[7] Full results for the Markov-switching models are available upon request.

[8] The two short-lived switches (in the late 1960s to mid-1970s and in the 2000s) would not be captured in the Bai-Perron approach that requires a minimum number of observations between each breakpoint.

[9] We also conduct predictive regressions for each identified regimes, or breakpoint, to examine changes in the coefficient sign, size and significance over the sample period. These results are available upon request and do reveal changes in coefficient sign for the Fed1 and Fed3 series, as well as changes in coefficient magnitude for all Fed series. The results are most stable for the Fed2 series, but the coefficient does vary such that the highest coefficient value is more than double the magnitude of the lowest.

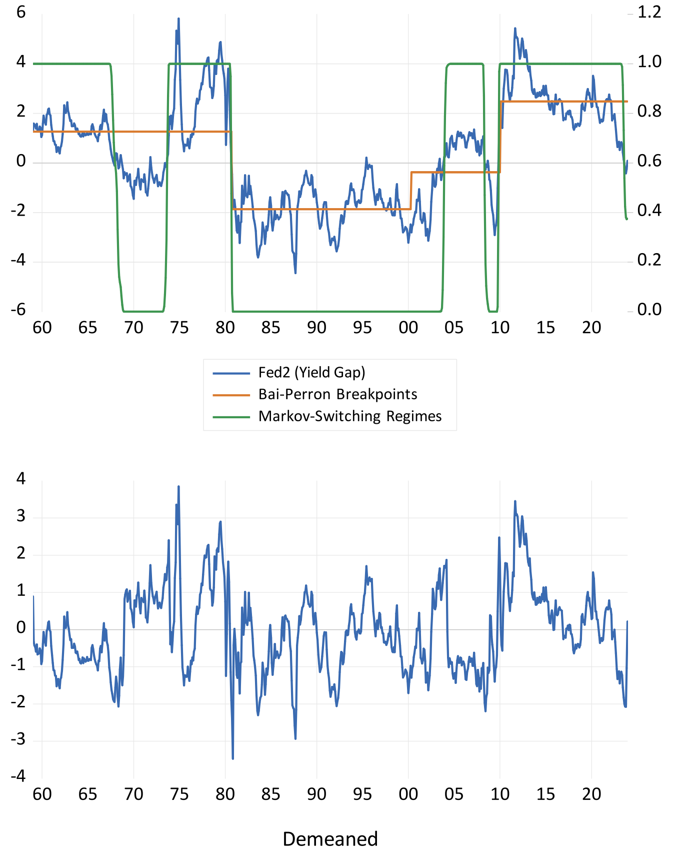

Fig. 4. Fed2 Markov switching.

Table 4
Predictive regression – Breakpoint adjusted fed series.

	Fed1			Fed2			Fed3		
Series	K = 1								
Fed	0.910^{a}	0.894^{a}	0.806^{b}	0.398^{a}	0.465^{a}	0.368^{b}	0.724	0.827	−1.168
	(3.56)	(3.23)	(2.57)	(3.07)	(3.39)	(2.14)	(0.084)	(0.90)	(−0.86)
EP		0.027	0.225^{c}		−0.055	0.095		0.011	0.483^{b}
		(0.40)	(1.75)		(−0.75)	(0.58)		(0.16)	(2.17)
TS		0.173	0.230		0.176	0.222		0.195	0.242
		(1.23)	(1.47)		(1.28)	(1.46)		(1.45)	(1.59)
Adj-R2	0.012	0.012	0.018	0.018	0.021	0.020	0.002	0.003	0.010
	K = 3								
Fed	2.536^{a}	2.458^{a}	2.190^{b}	1.188^{a}	1.335^{a}	1.049^{b}	2.258	2.287	−4.168
	(3.64)	(3.20)	(2.51)	(3.32)	(3.51)	(2.27)	(0.88)	(0.84)	(−1.01)
EP		0.128	0.732^{b}		−0.110	0.357		0.081	1.606^{b}
		(0.68)	(2.00)		(−0.53)	(0.79)		(0.41)	(2.29)
TS		0.447	0.588		0.455	0.565		0.496	0.622
		(1.20)	(1.47)		(1.26)	(1.44)		(1.38)	(1.58)
Adj-R2	0.024	0.028	0.042	0.042	0.048	0.048	0.007	0.011	0.031
			K = 12						
Fed	7.488^{a}	7.592^{a}	6.858^{a}	3.631^{a}	3.801^{a}	3.106^{b}	9.149	8.793	−8.450
	(3.64)	(3.10)	(2.61)	(3.88)	(3.31)	(2.57)	(1.32)	(1.21)	(−0.76)
EP		0.849^{c}	2.783^{a}		0.175	1.669		0.575	4.631^{a}
		(1.73)	(2.86)		(0.30)	(1.40)		(1.11)	(2.52)
TS		2.702^{a}	3.009^{b}		2.662^{a}	2.864^{b}		2.690^{b}	2.854^{b}
		(2.64)	(2.49)		(2.70)	(2.42)		(2.55)	(2.38)
Adj-R2	0.042	0.094	0.115	0.084	0.123	0.125	0.026	0.070	0.086

Notes: Entries are the coefficients, Newey-West *t*-statistics and Adjusted R-squared value for equation (10). The Fed model series are the Bai-Perron breakpoint de-meaned series, as observed in Fig. 3. The third column of results in each Fed panel also allows for Bai-Perron breaks in the EP and TS series. The superscript letters ‘a’, ‘b’, and ‘c’ refers to 1%, 5%, and 10% significance respectively.

Table 5
Predictive Regression – Markov-Switching Adjusted Fed Series (Regimes = 2).

Series	Fed1		Fed2		Fed3	
	K = 1					
Fed	0.704[a]	0.718[a]	0.436[a]	0.442[a]	0.165	−0.493
	(3.60)	(3.35)	(3.29)	(3.39)	(0.32)	(−0.33)
EP		0.065		−0.005		0.123
		(0.93)		(−0.07)		(0.59)
TS		0.169		0.164		0.171
		(1.22)		(1.17)		(1.28)
Adj-R2	0.011	0.013	0.017	0.018	−0.001	0.001
	K = 3					
Fed	2.124[a]	2.191[a]	1.365[a]	1.361[a]	0.632	−2.724
	(3.76)	(3.48)	(3.63)	(3.75)	(0.43)	(−0.69)
EP		0.233		0.022		0.587
		(1.20)		(0.12)		(1.05)
TS		0.424		0.414		0.419
		(1.15)		(1.09)		(1.17)
Adj-R2	0.028	0.036	0.046	0.048	0.00	0.008
	K = 12					
Fed	6.504[a]	6.989[a]	3.781[a]	3.567[a]	3.866	−7.049
	(3.99)	(3.77)	(3.65)	(3.53)	(0.99)	(−0.74)
EP		1.153[b]		0.579		2.022
		(2.37)		(1.19)		(1.51)
TS		2.510[b]		2.502[b]		2.413[b]
		(2.42)		(2.33)		(2.29)
Adj-R2	0.057	0.118	0.075	0.114	0.009	0.054

Notes: Entries are the coefficients, Newey-West *t*-statistics and Adjusted R-squared value for equation (10). The Fed model series are the Markov-Switching adjusted series, which is illustrated for Fed2 in Fig. 4. The superscript letters 'a', 'b', and 'c' refers to 1%, 5%, and 10% significance respectively.

4.4. *Why breaks?*

The previous sets of results reveal the changing nature of the Fed series, its breaks (level-shifts) or regimes and that this impacts its (time-varying) predictive power. As such, it is important to consider why such breaks occur. We know that equity and bond yields, respectively, will move according to changes in interest rates, inflation and economic growth. For a break (level-shift) in the Fed series to occur this implies that, at a particular point of time, the two yields respond differently to a change in one of these variables (if both yields adjust in the same fashion, then no shift in the Fed series will be observed). Related, there is also renewed interest in understanding the co-movement of stocks and bonds and within this line of research, an understanding of how the covariance between inflation and output growth relates to these dynamics. Early research (see, for example, Li, 2002; Baele et al., 2010; d'Addona & Kind, 2006) consider the role played by interest rates, inflation and output growth individually in determining the correlation between stocks and bonds, while more recent work (see, for example, David & Veronesi, 2013; Song, 2017; Boon et al., 2020; Campbell et al., 2020) investigate the covariance between inflation and economic growth and how it acts as a driver for stock and bond returns. Therefore, in considering the potential determinants of the noted Fed breaks, we consider the impact of monetary policy regimes and changes within monetary and macroeconomic variables.

To consider the impact of monetary policy regimes on the movement of the Fed series, the top part of Fig. 5 presents the real interest rate (3-month Treasury yield minus the inflation rate) against the Bai and Perron identified breakpoints for the Fed2 series (yield gap). Evident from this figure is a negative relation between the real interest rate and the mean value of the yield gap over the sample. We can also tie these observations with monetary policy regimes as identified by Gavin (2018).[10] From the start of the sample until 1980, the real interest rate is mildly positive or close to zero (with the exception of the oil price shock induced large negative value). This is a period when relatively stable inflation of the early 1960s gave way to higher inflation of the later 1960s and, especially, 1970s. Real interest rates increased significantly at the start of the 1980s and this coincides with a fall in the Fed model and the switch in the relative position between equity and bond yields observed in Fig. 1. That is, we see bond yields respond more to a change in real interest rates than equity yields. This period coincides with the Volker reforms designed to establish price stability credibility for the Federal Reserve. This period extended into the great moderation and in which real interest rates were consistently higher than previously, except following the recession of the early 1990s. This period of higher real interest rates gave way, first following the dotcom crash when interest rates fell to historically (at that time) low levels, and second following the financial crisis period and the onset of quantitative easing shortly afterwards, when interest rates fell to even greater lows. With both events, we see an increase in the average value of the Fed model as real interest rates turn negative, and the equity yield again becoming greater than the bond yield.

[10] Gavin (2018) defines four policy regimes that are contained within the sample considered here. First, from 1965 until 1979 is regarded as a high inflation period. Second, from 1979 to 1982 is the period consistent with the Volker reforms. Third, the great moderation that convers from 1982 to 2008, and fourth, the zero interest rate policy regime from 2008 to 2015.

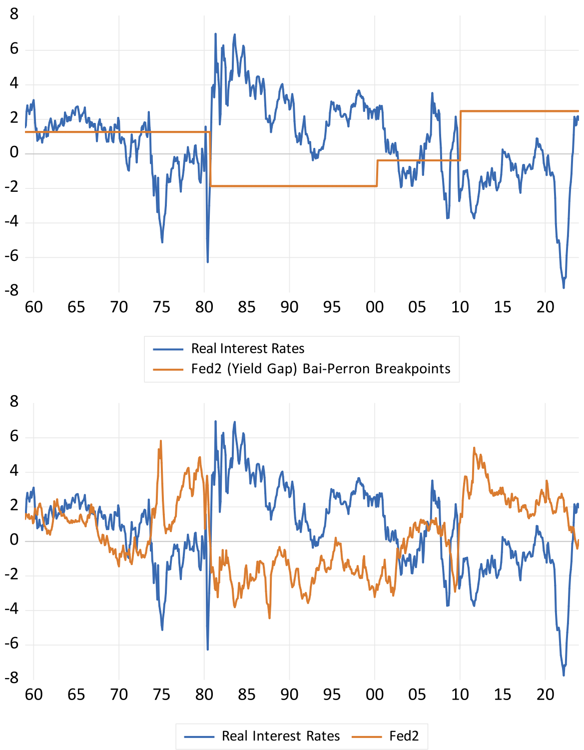

Fig. 5. Fed model and real interest rates.

Therefore, we can observe that lower (higher) real interest rates are associated with a higher (lower) Fed model series. This view is further supported by the lower part of Fig. 5, which presents both the Fed2 series and real interest rates. From this figure we can observe a strong negative relation between the Fed2 series and real interest rates, with their correlation at −0.62. This value is notably higher than the correlation between the Fed2 series and Treasury yields themselves (−0.51 for the 10-year yield and −0.39 for the 3-month yield).

The change in monetary policy regimes thus, can partly explain the breaks (or level-shifts) in the Fed ratio, but the nature of variable dynamics between these regimes, can also potentially hold part of the explanation. Specifically, the link between the nature of the monetary policy changes and economic conditions, i.e., between inflation and economic growth, and the movements in the two yields, which are linked to these economic variables. We can consider the expected relation between inflation, output and the two yield series. Higher inflation is directly linked to higher bond yields as investors require compensation for the erosion of nominal coupon payments. Empirically, there is also a positive relation between inflation and stock yields. This could arise as higher inflation leads to lower stock prices, which occurs for either rational reasons due to variation in the risk premium (e.g., Bekaert & Engstrom, 2010) or non-rational reasons due to money illusion (e.g., Campbell & Vuolteenaho, 2004) or difficulty in identify the correct signal (Sharpe, 2001).

Economic growth is also related to the equity and bond yield, although, arguably, the relation is less clear cut. Increasing growth leads to higher stock and lower bond prices, as risk is reduced, resulting in a negative relation with the equity yield and a positive relation with the bond yield. Specially, the reduction in risk will encourage investors to move away from bonds and towards stocks. Nonetheless, the opposite correlations could be argued for where higher growth will lead to an increase in earnings, a higher equity yield and a positive relation, while investors may increase their demand for all funds, bidding up the price of bonds (perhaps due to an expected future recession) and leading to a negative relation with the bond yield.

The relation between inflation and growth is expected to be negative (e.g., Fama, 1981; Fischer, 1993; Barro, 1995). Higher inflation will lead to a response by policy authorities leading to a future expected recession. Thus, household may postpone purchases. Equally, higher inflation reduces household purchasing power and leads to greater uncertainty, resulting in firms delaying investment decisions.

Recent evidence, however, suggests that the inflation and growth relation (referred to in the literature as the nominal-real relation) may switch from negative to positive. This, in turn, affects the relations between the yield variables considered here. In a lineage of work that considers the pricing of stocks and bonds and their return correlation, David and Veronesi (2013), Song (2017), Boon et al. (2020) and Campbell et al. (2020), among others, note the shift from negative to positive when considering the inflation and growth (either consumption or output) relation. This arises due to the changing economic circumstances across the period of time covered in our sample. The early part of the sample is dominated by fears that inflation is too high, with policy accordingly designed to control further increases, while in the latter part of the sample, fears surround the belief that inflation may be too low (and even deflationary).

Thus, higher inflation is regarded as 'bad' (i.e., leading to worsening economic conditions and a recession) in the former case, but 'good' (i.e., indicating growth) in the latter. The higher inflation of, for example, the 1970s is associated with a negative correlation with output growth. Here, the oil price shocks raised inflation and economic risk, leading to a fall in output and a subsequent recession. In contrast, after 2000, and especially after the financial crisis, higher inflation is an indication of improving economic conditions and lower economic risk. Thus, we now observe a positive correlation between inflation and output. Yet to be seen is how the correlation will subsequently develop following the heightened inflation of 2022.

This, in turn, has implications for the relation with the asset yields considered here. With a positive correlation between inflation and both equity and bonds yields, a negative correlation between inflation and output, equally leads to a negative relation between output and equity and bond yields. Accordingly, with higher inflation and lower output, both asset prices fall. However, once the relation between inflation and output switches to become positive, this, in turn, also leads to a positive correlation between output and asset yields. Fig. 6 presents 5-year rolling correlations between inflation, output growth as measured by industrial production and the two asset yields. As we can observe, the correlation between the yields and inflation remains positive throughout the sample with only transitory exceptions. This supports the view that higher inflation will lead to lower asset prices. The correlation between inflation and output growth is predominately negative from the start of the sample, again, with only short-lived exceptions. However, from, first, the post-dotcom crash and, second, the financial crisis, the correlation becomes increasingly positive. As seen, in the lower portion of Fig. 1, this is a period of (very) low inflation (and policy rates). This move, from a negative to a positive correlation between inflation and output growth in reflected in the relations between output growth and the two yields. To further support this view of changing correlations, Table 6 provides the sample correlation coefficients for the full sample and then for the 20-year periods corresponding to the start of the sample until the end of 1979, from 1980 to the end of 1999 and from 2000 to the end of the sample. The former two periods also correspond with negative correlations between output growth and all of inflation, equity and bond yields. However, after 2000, all these correlations become positive, confirming the evidence in Fig. 6.,[11][12]

In understanding the nature of the breaks in the Fed model series, we can observe two related processes. The first occurs with the breaks around 1980 when there is a notable change in the monetary policy stance, with substantially increased interest rates following the oil price shocks of the 1970s. These shocks led to double-digit inflation and a subsequent recession with bond yields rising greater than equity yields. The second occurs in two stages after 2000, when concern focuses on low growth, and where higher inflation is synonymous with a recovering economy. This causes a change in the nature of the relations between the variables. As noted, 2022 saw a rise in inflation following the Covid-19 period and the invasion of Ukraine, which led to an energy price shock. It will be of interest to observe how this affects the noted correlations going forward, while growth concerns remain.

4.5. *Predictability III*

The previous section highlights that the level-shifts in the Fed ratio can arise from changes in monetary policy regime and shifts in the nominal-real (inflation and output growth) relation. We consider this further by estimating the Fed model (we use Fed2, with other results available upon request) against the real interest rate to capture monetary policy regimes as indicated by Fig. 5 and the inflation-output correlation.[13] The residuals from this regression are then used to examine whether they exhibit predictive power for stock returns in a similar manner to the breakpoint and Markov-switching adjusted series.

Table 7 (Panel A) reports the results of estimating the Fed2 series against, first, the real interest rate only and, second, both the real interest rate and the inflation-growth correlation. Here we can see that the real interest rate has a highly significant negative relation consistent with the depiction in Fig. 5. The inflation-growth correlation also has a negative relation, but is only marginally (10 %) significant, nonetheless, there is an increase in the adjusted R-squared value, suggesting some information content. Table 7 (Panel B) reports the stock return predictability results using the adjusted Fed2 (residual) series from the Panel A regressions. Here, we can see that there is positive predictive power across each of the three horizons for both adjusted series (models), where the real interest rate only adjusted series has a marginally higher adjusted R-squared. We can also observe that while these models exhibit predictive power as with the breakpoint and Markov-switching adjusted Fed series results, the adjusted R-squared across each of the stock return horizons is lower than reported in Tables 4 and 5. This suggests that while the real interest rate and inflation-growth correlation provide some explanatory power for the level-shifts in the Fed series, there remains some additional (unmodelled) factor.[14]

Overall, the predictive regression results combined with the dynamics of the Fed series support the view that a broad relation exists

[11] This table also highlights the change in the correlation between stocks and bonds, which also switches sign in the latter part of the sample. Campbell et al. (2020) also relate this change to the switch in the nominal-real relation.

[12] We also consider predictive regressions for these different sub-samples. As also commented in footnote 9, there is a change in the strength of predictability over the sample. Here, predictability (for Fed2) is stronger in the latter two twenty-year periods, but significant in all. Cross-referencing this with the graphical evidence (e.g., Fig. 2), this is a period of greater stability in the Fed model series. Of note, the Fed coefficient is larger for k=1 and k=3 in the middle period, while for k=12, which looks beyond shorter dynamics, there is broader similarity across the three time periods.

[13] The correlations in Fig. 6 are obtained using a 5-year rolling window, while here, we estimate the DCC-GARCH approach (Engle, 2002) to provide greater robustness.

[14] Some experimentation was also undertaken to include the equity and bond yield correlation and the individual equity and bond yield volatilities in the Fed2 model regression. These additional variables are statistically significant and increase the explanatory power of the model for the Fed2 series but not for stock return predictability. Again, suggesting that further research is required.

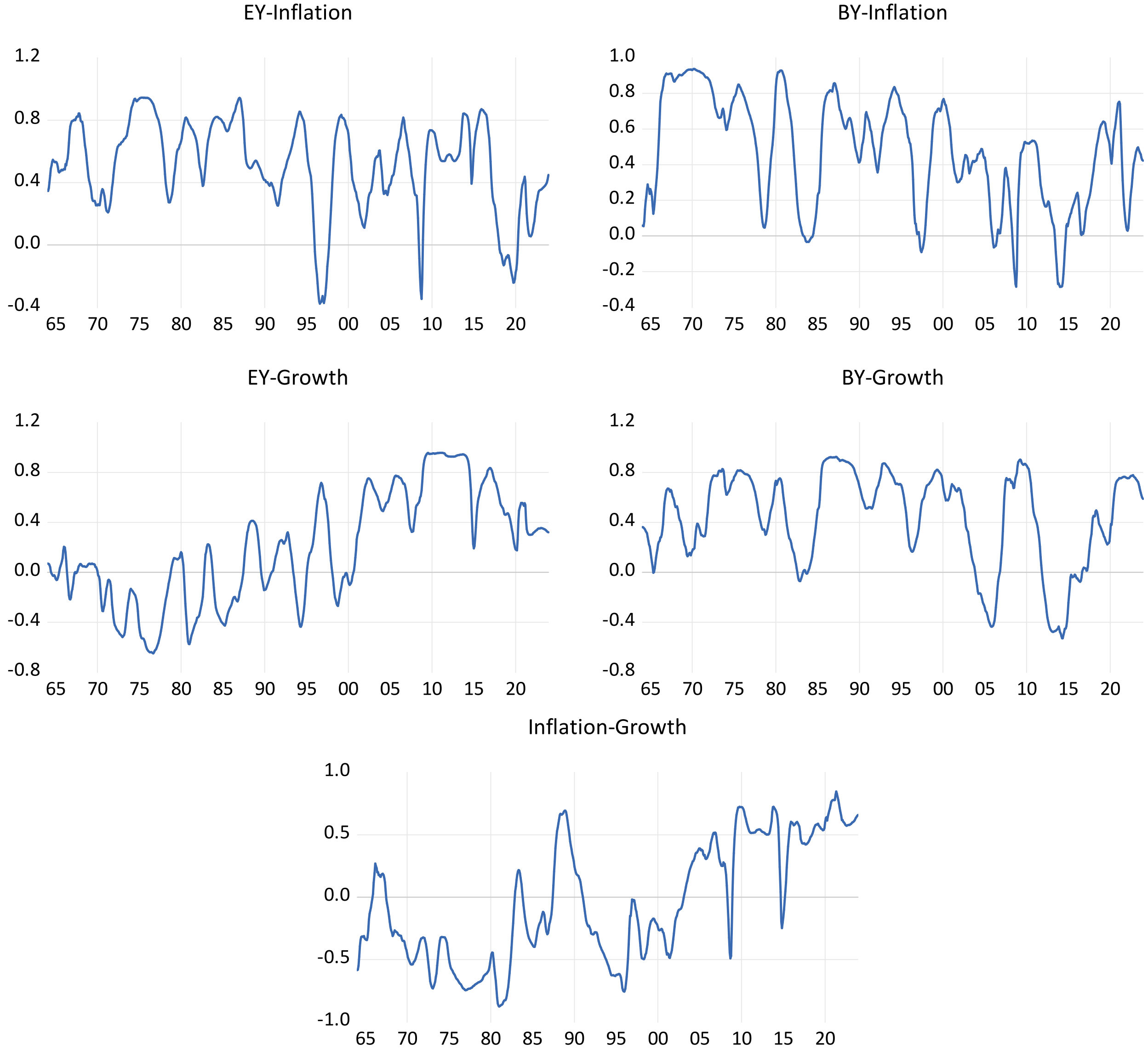

Fig. 6. 5-Year rolling correlations.

Table 6
Sample correlations.

	Inflation	Ind. Prd.	BY	EY	Inflation	Ind. Prd.	BY	EY
	Full Sample				1960:01–1979:12			
Infl	1	−0.07	0.65	0.80	1	−0.40	0.92	0.85
IP		1	0.06	0.07		1	−0.27	−0.20
BY			1	0.72			1	0.82
EY				1				1
	1980:01–1999:12				2000:01–2021:12			
Infl	1	−0.46	0.68	0.80	1	0.45	0.20	0.20
IP		1	−0.30	−0.40		1	0.16	0.63
BY			1	0.91			1	−0.12
EY				1				1

Notes: Entries are the correlation coefficients obtained over the full and noted sub-sample periods.

Table 7
Explaining the fed series and predictability.

Panel A. Explaining the Fed Series			
Fed2	Real Interest Rate	Corr. Inflation, Growth	Adj R-squared
Model 1	-0.549^{a} (−9.70)		0.382
Model 2	-0.545^{a} (−9.82)	-0.906^{c} (−1.68)	0.389
Panel B. Stock Return Predictability			
	K = 1	K = 3	K = 12
Model 1	0.262^{a}	0.777^{a}	1.910^{a}
	(2.59)	(2.72)	(2.87)
	[0.013]	[0.032]	[0.042]
Model 2	0.249^{b}	0.776^{a}	1.900^{a}
	(2.46)	(2.66)	(2.85)
	[0.012]	[0.031]	[0.041]

Notes: Panel A reports the coefficient estimates, Newey-West t-statistics and adjusted R-squared of the regression of Fed2 against the real interest rate and the DCC-GARCH correlation between inflation and output growth. Panel B reports the coefficients, Newey-West *t*-statistics and adjusted R-squared value for Eq. (10) with stock returns measured over k horizons against the Fed2 adjusted series as the residuals from the models in Panel A. The superscript letters 'a', 'b', and 'c' refers to 1%, 5%, and 10% significance respectively.

between the equity and bond yield series and that relation in turn contains information for subsequent stock returns but that there is not a single stable relation. Instead, the relation between the two yield series is prone to regime shifts (or breaks), which, in turn, result in changes to the predictive relation.

4.6. *Bond return predictability*

Focus within the literature in regard of the Fed model and its predictive power lies on stock returns. However, the construction of the Fed model variable includes both the stock and bond market. Therefore, it seems reasonable to ask whether there exists equivalent predictive power for bond returns. As discussed in Section 2, one motivation for the Fed model is that investors will move between stocks and bonds in order to achieve the highest yield and this is the mechanism that generates a stable relation between the two yields. A low stock price relative to earnings, for example, leads to a high equity yield and a higher Fed model. This encourages investors to move from bonds to stocks and so generating predictive power for subsequent stock returns with an expected positive predictive coefficient. Equally, as investors move away from bonds in this scenario, the subsequent bond return should fall generating negative predictive power. While this is not the primary focus of the paper, Table 8 reports the results from the predictive regression, equation (10), where bonds returns are now the dependent variable, and we include both the unadjusted and breakpoint adjusted explanatory variables.[15]

The results in Table 8 reveal no evidence of predictability arising from the unadjusted Fed model series, which, moreover, has the wrong coefficient sign at the one-month and one-quarter horizons (and the one-year horizon for Fed3). For the breakpoint adjusted Fed1 and Fed2 series, we do see evidence of negatively signed predictive power for $k = 12$ (one-year horizon). For Fed3, there is no evidence of predictive power. For the control variables, as with previously, there is greater evidence of predictability at the one-year horizon.

While there is less evidence of predictive power for bond returns than we find for stock returns, the results support the view that adjusting for level-shifts reveals greater predictability. The nature of the results also suggests the tendency for stocks, and the equity yield, to respond to changes in the bond yield. Where the equity and bond yields form a cointegrating set, the greater significance, and at shorter horizons, in the stock return equation, implies that the equity yield and not the bond yield, primarily responds to the disequilibrium error and this is consistent with the results of Zakamulin and Hunnes (2022).

5. Directional accuracy and crash prediction

The predictive regression results above seek to examine the ability of the Fed model to predict subsequent stock returns (i.e., point prediction). From an investor perspective, it is also the case that they are concerned about market direction as well as the potential for a crash. Specifically, an ability to predict market direction provides buy and sell signals. Further, predicting large negative stock market movements (crashes) will allow investors to adjust their portfolio positions.

To examine directional accuracy, we estimate the following equation:

$$I(r_{t+k}) = \alpha + \beta_1 Fed_t + \Sigma_i \delta_i x_{i,t} + \varepsilon_{t+k} \tag{11}$$

where $I(r_{t+k})$ represents an indicator [0,1] variable, while all other terms are the same as noted above, with the model estimated using

[15] Similarly, using the argument that the two yields form a cointegrating set, then the bonds return predictability equation represents the opposite part of that relation.

Table 8
Bond return predictability.

	Fed1		Fed2		Fed3	
	Original	BP Adjust.	Original	BP Adjust.	Original	BP Adjust.
Series	K = 1					
Fed	0.116	0.339[b]	0.048	0.225[b]	0.520	0.402
	(1.06)	(2.32)	(0.99)	(2.38)	(0.79)	(1.08)
EP	0.042	0.030	0.041	0.005	−0.042	0.011
	(0.75)	(0.53)	(0.74)	(0.09)	(−0.32)	(0.16)
TS	0.072	0.060	0.075	0.069	0.066	0.073
	(0.75)	(0.64)	(0.79)	(0.73)	(0.68)	(0.76)
Adj-R2	−0.001	0.002	−0.001	0.006	−0.002	−0.001
	K = 3					
Fed	−0.010	0.057	0.008	−0.013	0.940	1.034
	(−0.04)	(0.18)	(0.06)	(−0.05)	(0.56)	(1.08)
EP	0.186	0.185	0.186	0.188	0.040	0.115
	(1.31)	(1.29)	(1.31)	(1.21)	(0.12)	(0.66)
TS	0.378	0.380	0.382	0.379	0.388	0.412
	(1.43)	(1.44)	(1.43)	(1.43)	(1.45)	(1.54)
Adj-R2	0.016	0.016	0.016	0.016	0.017	0.020
	K = 12					
Fed	−1.082	−2.351[b]	−0.379	−1.106[b]	0.668	0.692
	(−1.48)	(−2.33)	(−1.11)	(−2.10)	(0.16)	(0.27)
EP	0.535	0.609	0.548	0.716	0.468	0.525
	(1.31)	(1.47)	(1.37)	(−1.63)	(0.52)	(1.01)
TS	1.210[b]	1.216[b]	1.219[b]	1.197[b]	1.342[b]	1.359[b]
	(2.00)	(1.98)	(2.04)	(1.98)	(2.23)	(2.29)
Adj-R2	0.066	0.072	0.063	0.071	0.053	0.054

Notes: Entries are the coefficients, Newey-West *t*-statistics and Adjusted R-squared value for equation (10) but with bond returns as the dependent variable. The Fed model series are the original and breakpoint adjusted series, with the latter illustrated in Fig. 3. The superscript letters 'a', 'b', and 'c' refers to 1%, 5%, and 10% significance respectively.

a probit approach. We define four versions of the indicator. The first three follow the flavour of the previous analysis with the indictor equal to one if returns over $k = 1, 3, 12$-month horizons are positive and zero if returns are negative. The fourth indicator is designed to capture a market crash and identifies negative returns of 10 % and over within a 12-month period as equal to one, with all other returns equal to zero.[16]

Table 9 presents the results of equation (11) for $k = 1$ and 3 and for the original and two adjusted Fed model series. In common with the results for returns predictability, we can see that the coefficients on the Fed1 and Fed2 series have a positive and significant effect at each horizon and for original and adjusted series (albeit now at the 5 % significance level for the adjusted Fed2 series). For the Fed3 series, only the breakpoint adjusted variable has a significant effect across the two horizons. Nonetheless, this contrasts with the previous set of results, for which the Fed3 was insignificant throughout. The positive coefficients support the view that an increase in the Fed model series is consistent with a positive return. Thus, a higher equity yield (and lower stock price relative to earnings) to bond yield predicts positive future returns. Conversely, for investors whose primary worry is about falls in the value of their stock portfolio, a lower value of the Fed series indicates an expected fall in the subsequent price. This is consistent with the results obtained in the returns prediction regressions.

For the control variables, we see that while the term structure is insignificant at the one-month horizon, it is positive and significant (including the 10 % level) at the one-quarter horizon. Thus, a steeper term structure, predicts positive future stock returns. The earnings-to-price ratio is largely insignificant across both horizons, with only a small number of exceptions. We can use the R-squared values as an indication of the preferred Fed model variant for each horizon. To provide a comparison and to consider whether the Fed series contains predictive information, we also include the results of a regression for the control variables only. For both the $k = 1$ and 3 horizons, the breakpoint adjusted Fed2 series is preferred, while the Markov-switching adjusted Fed2 series provides the second preferred regression. The regression that only includes the control variables achieves the lowest R-squared value, supporting the inclusion of the Fed series (although the Fed3 regressions achieve a similar value).

Table 10 extends the analysis from Table 9, first by considering directional accuracy prediction where $k = 12$ and second, by defining a market crash according to whether the price falls by 10 % (or more) during a 12-month period. This follows the same definition used in, for example, Lleo and Ziemba (2015, 2017), among others. The results, nonetheless, are broadly consistent with those reported in Table 9. For the one-year ($k = 12$) directional accuracy predictive regressions, the coefficients on the Fed1 and Fed2 series exhibit a positive and statistically significant result, while for Fed3, this is only seen with the breakpoint adjusted series. For the crash prediction results, we see a significant and negative predictive coefficient for each of the Fed model series (the negative coefficient is consistent with the previous results, given its construction as being equal to one if there is a 10 %, or more, stock crash).

[16] In terms of the number of observations where the dummy variable is equal to one, we have 477, 513 and 561 for the one-month, one-quarter and one-year horizons respectively and 107 for crash prediction.

Table 9
Directional accuracy – One/three month.

	Fed1	Fed2	Fed3	EP	TS	R2
Directional Accuracy: 1-Month						
No Fed				0.005	0.028	0.001
				(0.30)	(0.73)	
Fed1	0.196[a]			0.007	0.040	0.009
	(2.87)			(0.39)	(1.04)	
Fed2		0.053[b]		−0.003	0.045	0.006
		(2.28)		(−0.18)	(1.16)	
Fed3			0.187	−0.022	0.030	0.001
			(0.59)	(−0.44)	(0.78)	
Fed1-BP	0.317[a]			−0.004	0.025	0.008
	(2.76)			(−0.23)	(0.66)	
Fed2-BP		0.159[a]		−0.031	0.027	0.014
		(3.79)		(−1.53)	(0.70)	
Fed3-BP			0.340[c]	−0.011	0.036	0.004
			(1.81)	(−0.56)	(0.94)	
Fed1-MS	0.231[a]			0.009	0.025	0.007
	(2.61)			(0.50)	(0.66)	
Fed2-MS		0.130[a]		−0.011	0.025	0.009
		(3.00)		(−0.58)	(0.66)	
Fed3-MS			0.159	−0.018	0.029	0.001
			(0.47)	(−0.34)	(0.77)	
Directional Accuracy: 3-Months						
No Fed				−0.018	0.068[c]	0.005
				(−0.98)	(1.76)	
Fed1	0.231[a]			−0.016	0.081[b]	0.016
	(3.18)			(−0.89)	(2.09)	
Fed2		0.062[a]		−0.028	0.088[b]	0.012
		(2.64)		(−1.51)	(2.23)	
Fed3			0.310	−0.062	0.071[c]	0.006
			(0.95)	(−1.24)	(1.84)	
Fed1-BP	0.338[a]			−0.028	0.066[c]	0.013
	(2.75)			(−1.50)	(1.70)	
Fed2-BP		0.233[a]		−0.070	0.069[c]	0.034
		(5.37)		(−3.42)	(1.78)	
Fed3-BP			0.708[a]	−0.051	0.086[b]	0.018
			(3.71)	(−2.56)	(2.21)	
Fed1-MS	0.298[a]			−0.013	0.064[c]	0.015
	(3.11)			(−0.74)	(1.65)	
Fed2-MS		0.166[a]		−0.038	0.067[c]	0.019
		(3.73)		(−2.03)	(1.74)	
Fed3-MS			0.236	−0.052	0.070[c]	0.005
			(0.68)	(−0.96)	(1.80)	

Notes: Entries are the coefficients, *t*-statistics and McFadden R-squared value for equation (11). The models include the original, breakpoint (BP) and Markov-switching (MS) adjusted Fed model variants, as well as a model excluding the Fed series for comparison. The superscript letters 'a', 'b', and 'c' refers to 1%, 5%, and 10% significance respectively.

Considering the R-squared values across both of these exercises, the breakpoint adjusted Fed2 model is preferred with the Markov-switching adjusted Fed2 and the unadjusted Fed2 being second preferred for directional accuracy and crash prediction respectively. The term structure also exhibits significance throughout each exercise, while the earnings-to-price ratio exhibits greater significance than found at the shorter horizons. In notable contrast to the results of Table 9, there is now greater support for the Fed3 series also providing predictive power. Across the set of results, the Fed model provides information to investors in regard of market direction, offering the opportunity to adjust portfolios against such risk.

6. Forecasting

To complement the predictive power of the above models, we conduct a simple forecast exercise utilising measures based on both the size and sign of the forecast error. The forecasts are conducted using a recursive (expanding window) technique where the initial sample consists of the first five-years. A one-step ahead forecast is made, after which the end of the sample is expanded by one observation and the next forecast is obtained. This process continues until the end of the sample. The use of a recursive forecast approach allows the coefficients to vary over the sample and thus, should be able to capture time-variation in the predictive relation. The forecast measures used are designed to capture the size of the forecast errors, comparisons across benchmark and alternative models and the sign of the forecast error.

To provide standard measures of the size of the forecast errors, we include the mean squared error (MSE) and the R-squared value

Table 10
Directional accuracy and crash prediction – Twelve month.

	Fed1	Fed2	Fed3	EP	TS	R2
Directional Accuracy: 12-Months						
No Fed				0.068[a]	0.247[a]	0.043
				(3.33)	(5.67)	
Fed1	0.367[a]			0.072[a]	0.270[a]	0.068
	(4.41)			(3.47)	(6.12)	
Fed2		0.123[a]		0.049[b]	0.285[a]	0.068
		(4.70)		(2.32)	(6.36)	
Fed3			0.007	0.067	0.247[a]	0.043
			(0.02)	(1.20)	(5.64)	
Fed1-BP	0.466[a]			0.057a	0.258[a]	0.057
	(3.25)			(2.75)	(5.88)	
Fed2-BP		0.369[a]		−0.007	0.266[a]	0.111
		(7.57)		(−0.28)	(5.95)	
Fed3-BP			1.007[a]	0.016	0.282[a]	0.070
			(4.96)	(0.71)	(6.28)	
Fed1-MS	0.428[a]			0.078[a]	0.252[a]	0.063
	(3.93)			(3.75)	(5.75)	
−Fed2-MS		0.314[a]		0.036	0.258[a]	0.087
		(6.09)		(1.64)	(5.85)	
Fed3-MS			−0.084	0.081	0.246[a]	0.043
			(−0.22)	(1.33)	(5.64)	
Crash Prediction: 10 % Fall in 12-Months						
No Fed				−0.112[a]	−0.316[a]	0.074
				(−4.17)	(−5.88)	
Fed1	−0.526[a]			−0.115[a]	−0.347[a]	0.117
	(−4.49)			(−4.15)	(−6.32)	
Fed2		−0.185[a]		−0.091[a]	−0.370[a]	0.127
		(−5.51)		(−3.25)	(−6.66)	
Fed3			−0.873[b]	0.020	−0.332[a]	0.083
			(−2.40)	(0.34)	(−6.10)	
1-BP Adj	−0.392[b]			−0.104[a]	−0.322[a]	0.085
	(−2.37)			(−3.78)	(−5.97)	
2-BP Adj		−0.432[a]		−0.033	−0.322[a]	0.169
		(−7.36)		(−1.10)	(−5.84)	
3-BP Adj			−1.242[a]	−0.037	−0.357[a]	0.118
			(−6.27)	(−1.28)	(−6.44)	
1-MS	−0.378[a]			−0.119[a]	−0.325[a]	0.091
	(−2.91)			(−4.39)	(−5.99)	
2-MS		−0.245[a]		−0.087[a]	−0.327[a]	0.101
		(−4.01)		(−3.11)	(−6.05)	
3-MS			−0.820[b]	0.013	−0.329[a]	0.081
			(−2.12)	(0.20)	(−6.04)	

Notes: Entries are the coefficients, *t*-statistics and McFadden R-squared value for equation (11). The models include the original, breakpoint (BP) and Markov-switching (MS) adjusted Fed model variants, as well as a model excluding the Fed series for comparison. The superscript letters ‘a’, ‘b’, and ‘c’ refers to 1%, 5%, and 10% significance respectively.

from the Mincer-Zarnowitz (MZ) regression, with both given by:

$$MSE = (\sum_{t=1}^{\tau}(r_t - r_t^f)^2)/\tau \tag{12}$$

$$MZ : r_t = \alpha + \beta_1 r_t^f + \varepsilon_t \tag{13}$$

where τ is the forecast sample size, r_t is the actual return and r_t^f represents the forecast series
obtained from the predictive regression.

To consider comparative forecast performance more directly, we use two measures that compare a baseline forecast with a predictive regression, where the baseline forecast is obtained from a (recursive) historical mean model (i.e., equation (10) with only the constant term). Here, we consider the out-of-sample (OOS) R-squared value of Campbell and Thompson (2008) and Welch and Goyal (2008) and the forecast encompassing test that accompanies the above MZ regression. The former test is given by:

$$R_{oos}^2 = 1 - (\frac{\sum_{t=1}^{\tau}(r_t - r_t^{f_2})^2}{\sum_{t=1}^{\tau}(r_t - r_t^{f_1})^2}) \tag{14}$$

where, as above, τ is the forecast sample size, r_t is the actual return, while f_1 defines the baseline model tested against f_2, the predictor model. When the R^2_{oos} value is positive, the predictor model is preferred, i.e., has greater forecasting power than the baseline model. The forecast encompassing test regression is given by:

$$r_t = \alpha + \beta_1 r_t^{f_1} + \beta_2 r_t^{f_2} + \varepsilon_t \tag{15}$$

with all terms defined as above. Here, the baseline forecast is said to encompass the alternative, predictor, model forecast if β_2 is statistically insignificant. However, if β_2 is positive and statistically significant then the predictor model contains information beneficial for forecasting that is not captured by the baseline model.

While the above tests measure the size of the forecast error, it is equally important to consider the sign of the forecast error as this provides investor trading signals. Here, it is preferable to accurately predict market direction rather than to have a forecast value that is close (but maybe of opposite sign) to the realised value. One approach is to calculate the success ratio (SR), which measures the proportion of correctly forecast signs:

$$SR = \sum_{t=1}^{\tau} s_t \text{ where } s_t = I(r_t r_t^{f_i} > 0) = 1 \text{ ; } 0 \text{ otherwise.} \tag{16}$$

A SR value of one would indicate perfect sign predictability and a value of zero would indicate no sign predictability. Hence, in assessing the performance of each forecast model, we consider which model produces the highest SR value. To complement this measure, we also provide a simple trading rule approach. This is designed such that if the next periods forecast is positive then an investor buys the stock, while if the next periods forecast is negative then the investor (short) sells the stock. From this series, we then obtain the average trading return. Such an approach is initially considered in the work of Pesaran and Timmermann (1995), Pesaran and Timmermann (1992) and Marquering and Verbeek (2004) and more recently by, for example, Maio (2016), Baltas and Karyampas (2018) and Hammerschmid and Lohre (2018).

The results are presented in Table 11, where we consider several sets of benchmark and alternative predictor models based around equation (10). As benchmark models, we use the historical mean (constant only) model, which is a baseline commonly used in the literature. We also use an AR(1) model, as well as a model that includes only the control variables of the earnings-to-price ratio and the term structure, and a model that combines the AR(1) with the two control variables. As competing models, we include the Fed model variable into the predictor equation, and we do this is three alternative ways. First, we include the original Fed model variables. As noted, the use of recursive forecasts will allow time-variation to enter the predictive relation, although not explicitly in the form of breaks in the Fed series. Second, and to capture the breaks, we use the breakpoint adjusted Fed series. This assumes investors have perfect foresight in observing when the breaks will occur and thus, is not a pure forecast exercise. However, we believe it provides useful insight into forecast power. Third, and to address the drawbacks of the second approach, we recursively test for breakpoints and use this adjusted Fed series. This is to ensure that only 'real-time' information is used.[17]

In considering the totality of the results, we can see that the Fed1 and Fed2 models that assume the breakpoints are known, broadly provide the best forecasts across the different measures (with the Fed2 preferred); although it is acknowledged that these are not true forecasts. Regarding the forecasts that do only use information that would be available in real-time, we can see that all the predictor models outperform the historical mean baseline model. The only exception is the benchmark model that includes the two control variables of the earnings-to-price ratio and term structure, which achieves similar performance with the historical mean model. When comparing the Fed predictor models against the AR(1) benchmark, the nature of the results is more nuanced.[18] With regard to the statistical based forecast measures, the AR(1) occasionally achieves a lower MSE and higher out-of-sample R-squared, especially compared to the Fed3 series. Further, the Mincer-Zarnowitz R-squared and encompassing test coefficient and t-statistic are of greater magnitude in several cases.[19] However, the more economic based measures, the success ratio that provides trading signals and the trading rule itself, are more supportive of the models that include the Fed model series. Notably, the Fed2 model that uses real-time updating breakpoints is preferred on the basis of these latter two measures. Of interest, the Fed3 series typically performs worse than the two alternative representations of the Fed model.

7. Summary and conclusion

This paper considers whether the Fed model, the stable relation between equity and bond yields, (still) exists and whether it exhibits predictive power for subsequent stock returns. The empirical finance literature lacks a consensus in regard of the relation between the two yields. While a positive correlation is well-noted, the existence of a stable relation is questioned and, in turn, whether it provides a signal to the movement of subsequent returns. However, past results are mixed, with a suggestion that any supportive evidence may be sample specific. This overlies an equally mixed theoretical literature.

We consider three variants of the Fed model using both the ratio and difference in the two yields, with graphical evidence suggesting that any stable relation between them may be punctuated by breaks or regime changes. Full sample predictive regression are, at best, mixed and this appears consistent with established literature. Using both breakpoint tests and a Markov-switching regression,

[17] This is similar to the approach taken by Lettau and van Nieuwerburgh (2007).

[18] The benchmark AR(1) outperforms the alternative benchmark models that include the earnings-to-price and term structure variables.

[19] Again, the main exception to this being when the breakpoints are assumed known.

Table 11
Forecast results.

	MSE	MZ	OOS-R2	Enc	SR	TR (%)
Benchmark Models						
HM	0.133	0.0001	–	–	0.61	0.566
AR	0.129	0.033	0.035	0.909 (4.32)	0.62	0.701
EP / TS	0.137	0.002	−0.012	0.105 (0.90)	0.58	0.574
AR / EP / TS	0.128	0.033	0.036	0.732 (3.56)	0.61	0.690
Fed Models						
Fed1	0.127	0.039	0.038	0.602 (4.49)	0.62	0.884
Fed2	0.127	0.035	0.038	0.597 (3.95)	0.62	0.820
Fed3	0.133	0.030	−0.001	0.274 (2.20)	0.60	0.796
Fed Models – Known Breaks						
Fed1	0.126	0.045	0.044	0.701 (5.42)	0.63	0.820
Fed2	0.125	0.058	0.046	0.720 (7.02)	0.66	1.146
Fed3	0.133	0.023	−0.001	0.368 (2.29)	0.62	0.800
Fed Models – Recursive Breaks						
Fed1	0.128	0.040	0.035	0.648 (4.26)	0.63	0.798
Fed2	0.127	0.045	0.037	0.685 (5.04)	0.63	0.901
Fed3	0.130	0.025	0.014	0.316 (2.16)	0.60	0.687

Notes: Entries are the results of the Mean Squared Error, equation (12), Mincer-Zarnowitz R-squared, equation (13), Out-Of-Sample R-squared, equation (14), Encompassing test, equation (15), Success Ratio, equation (16), and Trading Returns for the different predictive variants based on equation (10). The Fed model forecasts include the control variables in the forecast equation.

evidence of regimes of behaviour are uncovered that may explain the mixed nature of the empirical results. Of interest, movement in the Fed series varies in an inverse fashion with real interest rates. A relatively lower Fed series, which is consistent with higher stock prices relative to earnings and the bond yield, occurs when real interest rates are higher, which is notably observed during the 1980s and 1990s. Lower real interest rates, following successive crises (e.g., dotcom crash, the financial crisis and Covid-19) has, in turn, led to a higher Fed series. A change in the correlation between inflation and growth also appears linked to a shift in the Fed series. Here, a positive inflation-growth correlation is linked to positive relations with both yields. Together, this correlation and real interest rates provide a large degree of explanatory power for the Fed model breaks. Predictive regressions for both stock returns and directional accuracy (including crash prediction) and a small forecast exercise, reveals that accounting for regime dependence leads to improved prediction across a range of horizons. Evidence of bond return predictability is also noted at longer horizons.

The results presented here reveal several points of interest for both academics and investors. A positive relation between equity and bond yields is noted, but crucially, the relation is not stable over the full sample period. Instead, the relative values of the yields, either as a ratio or difference, vary over time. Notably, that variation is linked to movements in inflation, output and real interest rates. For example, higher real rates in the 1980s and 1990s, with lower values in the 1970s and 2000s and 2010s are consistent with a generally lower and higher Fed values respectively. As such, long-term cyclical movement in real interest rates provides information about relative equity and bond yield values. Furthermore, a switch in the inflation-growth relation imparts a further level-shift. When adjusting for these regimes of behaviour within the Fed series, stronger predictive evidence for stock (and bond) return predictability, both point and directions based, is uncovered. This adds to our understanding of financial markets, their interactions, and links with the real economy, improving investors knowledge base when building portfolios. However, a more formal model linking inflation and growth dynamics with the noted breaks, using, for example, a Markov-switching approach may provide further robustness to this conclusion and is left as an avenue for future research.

CRediT authorship contribution statement

David G. McMillan: Writing – review & editing, Writing – original draft, Visualization, Validation, Software, Resources, Project administration, Methodology, Investigation, Formal analysis, Data curation, Conceptualization.

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