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Monetary policy uncertainty, monetary policy surprises and stock returns☆

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ABSTRACT

We study the effects of monetary policy surprises on stock returns under low and high monetary policy uncertainty in the U.S. using the Panel Smooth Transition Regression (PSTR) model to identify the uncertainty regimes. Monetary policy surprises are unexpected changes in the Federal Funds Rate (FFR) on Federal Open Market Committee (FOMC) announcement days, where the mimicking portfolio method is used to obtain a regular time series with surprises since the announcements occur on an irregular basis. Using data for the period 1994–2008, we find a negative relationship between monetary policy surprises and stock returns under both uncertainty regimes but a less pronounced relationship between surprises and returns when uncertainty is low. Hence, it is more important to hedge against unexpected stock market volatility when the uncertainty in monetary policy is high compared to when uncertainty is low.

1. Introduction

Today, there is a voluminous body of literature in financial economics and macroeconomics on the effects of monetary policy decisions on stock returns. One reason why this literature has grown to such an extent during the last two decades is that the communication strategy by the Federal Reserve has changed from not announcing their policy decisions to the public to the use of a range of tools when communicating their decisions, such as the publication of statements and minutes by the Federal Open Market Committee (FOMC).

Thorbecke (1997) was among the first to make a convincing case against the nonneutrality of monetary policy—an often articulated view among scholars in the 1990s (see Black, 1987 for a prominent example of this view)—when he showed that stock returns responded to changes in monetary policy, measured as innovations in the Federal Funds Rate (FFR). His finding was in harmony with the dividend-discount model (DDM), where the stock price is equal to the present value of the expected stream of dividend payments. In other words, a monetary shock that increases stock returns hints that an expansionary monetary policy increases expected dividend payments because of higher earnings for the firms, decreases the discount factor of the dividend payments, or both.

Another example of an even earlier date on the effects of monetary policy decisions on stock returns is Rozeff (1974), who showed, as Thorbecke (1997) also did, that stock returns responded to monetary variables without lag—a finding consistent with the efficient market hypothesis. Rozeff (1974) pointed out that there is no conflict between the efficient market hypothesis and a monetary policy that affects asset prices without lag but that there is a potential conflict between the same hypothesis and a monetary policy that affects

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asset prices with lag.

Patelis (1997) moved the research on the relationship between monetary policy surprises and stock returns in a new direction when he employed the long-horizon methodology of Fama and French (1988) using monetary policy variables such as the FFR and showed that the predictability of stock returns increased with the time horizon. This result was in line with Fama and French (1988), who used dividend yields to forecast stock returns at various time horizons (see also Jensen et al., 1996, who extended the financial variables to not only include dividend yields). Patelis (1997) argued that his result was evidence that monetary policy surprises affected the risk structure of the economy and thereby stock returns.

After having established that monetary policy surprises do affect stock returns, greater interest among scholars has been devoted to a better understanding of whether returns on stocks with particular firm and stock characteristics are more sensitive to monetary policy surprises than stocks associated with other characteristics. Examples include Chava and Hsu (2020), who found that the stock returns of financially constrained firms were more sensitive to unexpected interest rate changes than those of unconstrained firms (see also Ehrmann & Fratzscher, 2004 and Ippolito et al., 2018 on financial constraints and stock returns), and Guo (2004), who found that the stock returns of small firms were more sensitive to unexpected interest rate changes than those of large firms (see Jensen & Mercer, 2002 on how firm size and book-to-market equity matter for stock returns).

Firm and stock characteristics are not the only issues that matter for how pronounced the relationship is between monetary policy decisions and stock returns. Chen (2007) found that monetary policy surprises had larger effects on stock returns in bear markets than in bull markets, and Basistha and Kurov (2008) found that monetary policy surprises had larger effects on stock returns in recessions. Moreover, regarding the asymmetric effects of unexpected interest rate changes on stock returns, Lobo (2000) found that the stock market overreacted in the wake of bad news, and Lobo (2002) found that unexpected increases in the interest rate temporarily increased stock market volatility on the announcement day of the monetary policy decision.

Kuttner (2001) made a valuable contribution to the literature when he showed how data from the futures market around FOMC meeting days could be used to separate changes in the FFR into anticipated and unanticipated changes. By using Kuttner's (2001) method, which we also do here when we study how stock returns have been affected by monetary policy surprises under low and high monetary policy uncertainty, Bernanke and Kuttner (2005) showed that an expansionary (a contractionary) monetary policy by the Federal Reserve increased (decreased) U.S. stock returns (see also Bomfim, 2003 for another application of Kuttner's method, where he found that a positive monetary policy surprise had a larger effect on stock market volatility than a negative surprise).

In recent years, there has been increased interest among scholars in how uncertainty in different policy matters may affect the economy. For this reason, several measures of policy uncertainty have been developed in the literature. Prominent examples are the overall economic policy uncertainty indexes by Baker et al. (2016a) and Baker et al. (2016b), which are based on the occurrence of certain keywords in newspapers. Measures of fiscal, monetary, national security, and regulatory policies are examples of components included in these indexes. Baker et al. (2016a) also contains pure monetary policy uncertainty indexes.

Our contribution to the literature is that we examine how the monetary policy-stock return relationship has been affected by the level of uncertainty in monetary policy decisions made by the Federal Reserve. Specifically, we study the effects of monetary policy surprises on stock returns under low and high monetary policy uncertainty in the U.S. during 1994–2008 and 1994–2015 using the Panel Smooth Transition Regression (PSTR) model by González et al. (2017) to identify the uncertainty regimes. Monetary policy surprises are unexpected changes in the FFR on FOMC announcement days, where the mimicking portfolio method is used to obtain a regular time series with surprises since the announcements occur on an irregular basis. One of the indexes in Baker et al. (2016a) is used as the measure of monetary policy uncertainty.

The PSTR model can be viewed as a generalization of the threshold regression model developed by Hansen (1999) in the sense that it allows the regression parameters in the model to change smoothly when moving from one regime to another. Our choice of the PSTR model for the empirical analysis is motivated by the fact that the regimes—in our setting, representing two levels of monetary policy uncertainty—are determined endogenously within the model. Turning to the mimicking portfolio method, a mimicking portfolio is a tradeable portfolio of assets engineered to closely match the factor sensitivities of a tradable quantity, such as a portfolio of assets, or a nontradable quantity, such as macroeconomic news. For this reason, the mimicking portfolio method is useful to generate data on monetary policy surprises (see Vassalou, 2003). In addition, the mimicking portfolio method is useful from the perspective of reducing noise in the asset pricing model stemming from the underlying factors (see Pukthuanthong et al., 2020).

We study the relationship between monetary policy surprises and stock returns under different levels of monetary policy uncertainty to make a distinction between the 'environment' in which monetary policy is conducted, which can be more or less uncertain, and the monetary policy itself, which can be more or less surprising. That is, does a surprising monetary policy of a given magnitude have a larger or smaller effect on stock returns when the 'environment' for monetary policy is more uncertain compared with less uncertain? Or, to put the question in the context of risk management, is it more important to hedge against unexpected stock market volatility when monetary policy uncertainty is high rather than when it is low?

Hence, the approach taken here resembles the idea proposed in Bask and de Luna (2002) and Bask (2010) in the sense that the stability of a dynamic system (here, the 'environment') should be contrasted with the volatility of the time series generated by the system (here, the stock returns). Specifically, in Bask and de Luna (2002), this idea was developed theoretically by presenting not only a measure of the stability of a stochastic dynamic system but also a consistent estimator of the proposed measure. The idea was further refined and named (λ, σ^2)-analysis in Bask (2010). The proposed method in Bask and de Luna (2002) and Bask (2010) was applied in Bask and de Luna (2005) using exchange rate data, in Bask and Widerberg (2009) using electricity price data, and in Bask and Widerberg (2012) using stock price data.

Using data for the period 1994–2008, we find a negative relationship between monetary policy surprises by the Federal Reserve and

U.S. stock returns under both low and high monetary policy uncertainty; this relationship is *less* pronounced when uncertainty is low. If the data set is extended to also include the period of the zero interest policy during 2009–2015, we again find a negative relationship between surprises and returns under both uncertainty regimes but a *more* pronounced relationship between the variables when uncertainty is low. In other words, a positive monetary policy surprise—that is, a monetary policy that is more contractionary, or less expansionary, than expected by market participants—decreases stock returns, where a positive surprise has a larger (smaller) effect on stock returns for the period 1994–2008 (1994–2015) when monetary policy uncertainty is high compared to when it is low.

Bauer et al. (2022) should be mentioned in this context since they also studied the monetary policy-stock return relationship, albeit in a different setting. Bauer et al. (2022) utilized a derivatives-based measure of monetary policy uncertainty and showed that stock returns, measured by the S&P 500 index, responded more to monetary policy surprises when uncertainty just before a FOMC meeting was low. Thus, we found a similar result for the period 1994–2015 as Bauer et al. (2022). However, a crucial difference between Bauer et al. (2022) and our paper is that they studied how changes in monetary policy uncertainty around FOMC announcements—referred to as the 'FOMC uncertainty cycle'—have affected the monetary policy-stock return relationship, whereas we study how periods of low and high monetary policy uncertainty affect the same relationship. Consequently, as opposed to what we do in this paper, Bauer et al. (2022) used an event study methodology in their empirical analysis.

De Pooter et al. (2021) should also be mentioned in this context, although they did not study the monetary policy-stock return relationship. They examined how uncertainty in the decisions made by the Federal Reserve, utilizing a derivatives-based measure of uncertainty, affected the transmission of monetary policy shocks to longer-term nominal and real yields. They found that the reaction of yields was more pronounced when monetary policy uncertainty was low than when uncertainty was high. Hence, De Pooter et al. (2021) found, as we do for the 1994–2015 period, a more pronounced relationship between monetary policy and the outcome variable—yield respective stock return—when the uncertainty in the Federal Reserve's policy is low. They were also able to establish that their result was driven by investors taking riskier positions when monetary policy uncertainty was low, which means that investors had to make abrupt adjustments in their portfolios when the Federal Reserve made an unexpected decision.

The rest of this paper is organized as follows. A theoretical construct is presented in Section 2, the methodological framework and the data set are presented in Section 3, the empirical analysis is found in Section 4, and Section 5 ends the paper with a discussion of the findings.

2. Theoretical construct

Let us examine the DDM with constant dividend payments to see which insights this model can provide that are related to the theme in this paper:

$$S_t = \frac{D}{R_t} \tag{1}$$

where S_t is the stock price, D is the constant dividend payment, and R_t is the discount rate of future dividend payments. When dividend payments are not constant but *almost constant*, the DDM in Eq. (1) can be approximated by

$$S_t \cong \frac{D_t^e}{R_t^e} \tag{2}$$

where the superscript e denotes expectations.

We express the DDM as we do in Eq. (2) because we would like to introduce monetary policy uncertainty into the model. Specifically, we assume that the degree of monetary policy uncertainty is expressed as the variation in the expected discount rate because it is influenced by the central bank's expected policy, which can be more or less uncertain, where a large (small) variation in the expected discount rate mirrors a high (low) degree of uncertainty in the central bank's policy.

After taking the logarithm of both sides of the DDM in Eq. (2), we have

$$s_t \cong d_t^e - r_t^e \tag{3}$$

where the variables expressed in lowercase letters are the logarithms of the corresponding variables expressed in uppercase letters. Then, after taking the variance of both sides of the DDM in Eq. (3), we have

$$\mathrm{var}(s_t) \cong \mathrm{var}\left(d_t^e - r_t^e\right) = \mathrm{var}\left(d_t^e\right) + \mathrm{var}\left(-r_t^e\right) + 2\cdot\mathrm{cov}\left(d_t^e, -r_t^e\right) \approx var\left(r_t^e\right) - 2\cdot cov\left(d_t^e, r_t^e\right) \tag{4}$$

or

$$\frac{\Delta\mathrm{var}(s_t)}{\Delta\mathrm{var}\left(r_t^e\right)} \approx 1 - 2\cdot\frac{\Delta\mathrm{cov}\left(d_t^e, r_t^e\right)}{\Delta\mathrm{var}\left(r_t^e\right)} \tag{5}$$

where the stock price variance ($\mathrm{var}(s_t)$) is a proxy for stock returns and the variance in dividend payments is small ($\mathrm{var}\left(d_t^e\right) \approx 0$) because the payments are assumed to be almost constant. Moreover, when monetary policy uncertainty is low, the variance in the discount rate ($\mathrm{var}\left(r_t^e\right)$) in Eq. (4) is small, and when uncertainty is high, the variance in the discount rate is large.

Hence, when

$$\frac{\Delta \mathrm{var}(s_t)}{\Delta \mathrm{var}(r_t^e)} \approx 1 - 2 \cdot \frac{\Delta \mathrm{cov}(d_t^e, r_t^e)}{\Delta \mathrm{var}(r_t^e)} < 0 \tag{6}$$

or

$$\Delta \mathrm{cov}(d_t^e, r_t^e) \gtrsim 0.5 \cdot \Delta \mathrm{var}(r_t^e) \tag{7}$$

we have a more pronounced relationship between monetary policy surprises and stock returns when monetary policy uncertainty is low compared to when it is high. The interpretation of Eq. (7) is that it is necessary for the covariance between dividend payments and the discount rate to increase when the uncertainty in monetary policy changes from low to high. Evidently, it is not necessary for the covariance between the variables to be positive. What matters is whether this covariance becomes less negative, more positive, or changes its sign from negative to positive.

There are qualitative reasons why the conditions in Eqs. (6)–(7) might be satisfied, as the following *hypothetical* example demonstrates. First, there is a negative relationship between dividends paid by firms and the interest rate set by the monetary authority ($\mathrm{cov}(d_t^e, r_t^e) < 0$) when the economy is in a normal state and monetary policy is surrounded by low uncertainty ($\mathrm{var}(r_t^e)$ small). The intuition is that an expansionary (a contractionary) monetary policy in the form of a decreased (an increased) interest rate will increase (decrease) firms' earnings and thereby also increase (decrease) dividend payments.

However, if we continue with the hypothetical example, the relationship between dividends paid by firms and the interest rate set by the monetary authority becomes positive when the economy turns into a recessional state. The intuition is that dividend payments fall when firms' earnings are lower at the same time as the central bank lowers the interest rate to fuel the economy ($\mathrm{cov}(d_t^e, r_t^e) > 0$). That is, the covariance between dividend payments and the interest rate increases from negative to positive when the uncertainty in monetary policy changes from low to high. In addition, when the state of the economy worsens, monetary policy is surrounded by high uncertainty ($\mathrm{var}(r_t^e)$ large). If the changed covariance between dividend payments and the discount rate is large enough when the economy turns into a recessional state, then the condition in Eq. (7) is satisfied, and we have a more pronounced monetary policy-stock return relationship when monetary policy uncertainty is low compared to when it is high.

Furthermore, when

$$\frac{\Delta \mathrm{var}(s_t)}{\Delta \mathrm{var}(r_t^e)} \approx 1 - 2 \cdot \frac{\Delta \mathrm{cov}(d_t^e, r_t^e)}{\Delta \mathrm{var}(r_t^e)} > 0 \tag{8}$$

or

$$\Delta \mathrm{cov}(d_t^e, r_t^e) \lesssim 0.5 \cdot \Delta \mathrm{var}(r_t^e) \tag{9}$$

we have a less pronounced relationship between monetary policy surprises and stock returns when monetary policy uncertainty is low compared to when it is high. Of course, with the abovementioned hypothetical example in mind, it could still be the case that the covariance between dividend payments and the discount rate increases when the uncertainty in monetary policy changes from low to high, but the change in the covariance is not large enough to satisfy Eqs. (6)–(7). Finally, when dividend payments are constant and unaffected by the level of uncertainty in monetary policy ($\Delta cov(d_t^e, r_t^e) = 0$), Eqs. (8)–(9) are satisfied, and stock returns react more strongly to monetary policy surprises when uncertainty is high than when it is low.

3. Methodological framework and data set

To investigate how monetary policy surprises affect stock returns under low and high monetary policy uncertainty, we embed the Intertemporal Capital Asset Pricing Model (ICAPM) into a two-regime PSTR model (see González et al., 2017):

$$r_{n\in[1,\ldots,N],t\in[1,\ldots,T]} = \mu_n + \lambda_t + \beta_0 \mathrm{B}_{n,t} + \beta_1 \Delta i_t^{u,reg} + \beta_2 \Delta i_t^{u,reg} g(q_t;\gamma,c) + \varepsilon_{n,t} \tag{10}$$

where $r_{n,t}$ is the excess return at time t on portfolio n formed on firm or stock characteristics, μ_n is the cross-sectional fixed effect, λ_t is the time effect, $\mathrm{B}_{n,t}$ is the portfolio's market beta, $\Delta i_t^{u,reg}$ is the return on the mimicking portfolio that proxies the monetary policy surprise, $g(\bullet)$ is the transition function with the transition variable q_t that measures monetary policy uncertainty, and $\varepsilon_{n,t}$ is the error. Moreover, the transition function $g(\bullet)$ is an increasing logistic function in the transition variable q_t (see González et al., 2017, Teräsvirta, 1994, and Teräsvirta et al., 2010):

$$g(q_t;\gamma,c) = (1 + \exp(-\gamma(q_t - c)))^{-1} \tag{11}$$

where $\gamma > 0$ is the slope parameter and c is the location parameter.

The excess returns on the portfolios in the pooled regression in Eqs. (10)–(11) are exposed to monetary policy surprises under low monetary policy uncertainty when $q_t \to -\infty$, and the excess returns on the same portfolios are exposed to monetary policy surprises under high monetary policy uncertainty when $q_t \to \infty$. Be aware that the PSTR model in Eqs. (10)–(11) allows for an infinite number of intermediate regimes, each characterized by a different value of the transition function between zero and one. We focus on the two extreme regimes when the transition function equals either zero or one.

We use the Monetary Policy Uncertainty (MPU) index in Baker et al. (2016a) that is derived from articles in ten large newspapers[1] as the transition variable q_t in the PSTR model in Eqs. (10)–(11). See Fig. 1 for the time series of the MPU index during 1994–2015. Spikes with high monetary policy uncertainty occurred, first and foremost, in connection with the September 11 attacks in 2001 but also in the aftermath of the bursting dot-com bubble in 2000–2002, at the onset of the financial crisis in 2008–2009, and after the downgrading of the U.S. federal government credit rating in 2011.

The parameters in the PSTR model in Eq. (10) of key interest in the empirical analysis are β_1 and β_2, where β_1 measures the effect of monetary policy surprises on portfolio returns under low monetary policy uncertainty and, thereby, the effect on stock returns under low monetary policy uncertainty, and $\beta_1 + \beta_2$ measures the effect of monetary policy surprises on stock returns under high monetary policy uncertainty. Consequently, β_2 measures how the effects of monetary policy surprises on stock returns differ under low and high monetary policy uncertainty.

Four sets of portfolios are used in the regressions in Eqs. (10)–(11), with one regression for each set of portfolios: (i) 25 portfolios formed on size and book-to-market; (ii) 25 portfolios formed on size and momentum; (iii) 32 portfolios formed on size, operating profitability, and investment; and (iv) 12 industry portfolios, where the excess returns on the 94 portfolios represent the cross-section of stock returns. We use these portfolios because the returns on the stocks included in the portfolios have successfully explained the returns for a large number of stocks (see Fama & French, 1993, Fama & French, 1997, and Fama & French, 2015).

Finally, to run the regressions in Eqs. (10)–(11), measures of monetary policy surprises ($\Delta i_t^{u,reg}$) and portfolios' market betas ($\mathrm{B}_{n,t}$) are needed. How to obtain measures of those variables is explained in Sections 3.1–3.2.

3.1. Measuring monetary policy surprises

To measure the surprise component of a change in the FFR and thereby to measure the monetary policy surprise, we examine how the federal funds futures rate has changed between the FOMC announcement day and the previous trading day. This is an adequate measure of the unexpected change in the FFR because federal funds futures contracts reveal what market participants believe the FFR will be when the contracts expire. We follow the literature closely when determining the sizes of monetary policy surprises (see Bernanke & Kuttner, 2005 and Kuttner, 2001).

To fix notations, let $f_{m,d}^n$ denote the federal funds futures rate, where m is the month, d is the day of the month, and $m+n$ is the month for the cash settlement, which is on the last business day of the month. Then, the unexpected change in the FFR (Δi^u) on day d of month m is defined as

$$\Delta i_{m,d}^u \equiv \frac{D_m}{D_m - d} \cdot \left(f_{m,d}^0 - f_{m-1,D_{m-1}}^1 \right) \Big|_{d=1} \tag{12}$$

$$\Delta i_{m,d}^u \equiv \frac{D_m}{D_m - d} \cdot \left(f_{m,d}^0 - f_{m,d-1}^0 \right) \Big|_{1<d<D_m-2} \tag{13}$$

or

$$\Delta i_{m,d}^u \equiv f_{m,d}^1 - f_{m,d-1}^1 \Big|_{d \geq D_m-2} \tag{14}$$

where D_m is the number of days in month m. The parameter $\frac{D_m}{D_m-d}$ is included in Eqs. (12)-(13) because the contracts' settlement price is based on the monthly average FFR, and the change in the federal funds futures rate must be scaled up by a factor related to the number of days in the month affected by the change (see Kuttner, 2001 for a detailed explanation of the definition of $\Delta i_{m,d}^u$).

Because the FOMC announcements occur on an irregular basis, the observations in the time series $\{\Delta i_t^u\}$ are not regular. The mimicking portfolio method is therefore used to obtain a regular time series (see Vassalou, 2003), where our measure of monetary policy surprises is regressed on the returns on six portfolios formed on size and book-to-market and the returns on the momentum portfolio:

$$\Delta i_t^u = const. + \alpha X_t^d + \epsilon_t \tag{15}$$

where $X_t^d = \left[FF_t^d, MOM_t^d \right]'$ is a vector of daily excess returns on the portfolios, α is a vector of regression coefficients, and ϵ_t is the error. Specifically, FF_t^d in X_t^d is a vector of daily excess returns on the six portfolios formed on size and book-to-market, and MOM_t^d in X_t^d is the daily excess return on the momentum portfolio. We use these returns because they have successfully explained the returns for a large number of stocks (see Fama & French, 1993 and Carhart, 1997).

The monthly return on the mimicking portfolio is then defined as

[1] The newspapers are the Boston Globe, the Chicago Tribune, the Dallas Morning News, the Houston Chronicle, the Los Angeles Times, the Miami Herald, the San Francisco Chronicle, USA Today, the Wall Street Journal, and the Washington Post.

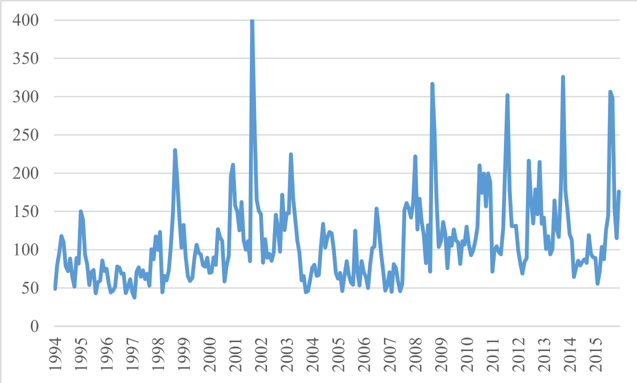

Fig. 1. The MPU index.

$$\Delta i_t^{u,reg} \equiv \frac{\widehat{\alpha}}{\|\widehat{\alpha}\|} \cdot X_t^m \tag{16}$$

where $X_t^m = \left[FF_t^m, MOM_t^m\right]'$ is a vector of monthly excess returns on the six Fama-French portfolios and the momentum portfolio. For convenient scaling, the vector $\frac{\widehat{\alpha}}{\|\widehat{\alpha}\|}$ has length one. The observations in the time series $\left\{\Delta i_t^{u,reg}\right\}$ are regular by construction.

The return on the mimicking portfolio in Eq. (16) is defined as the excess return on a linear combination of portfolios, which explains why we have not subtracted the risk-free rate of return from the mimicking portfolio return in Eq. (10). In other words, the return on the mimicking portfolio in Eq. (16) is already expressed in excess return.

3.2. Measuring the portfolios' market betas

The portfolios' market betas are estimated using the market model:

$$r_{n,t} = const. + \mathrm{B}_{n,t} r_t^{market} + \mathscr{E}_{n,t} \tag{17}$$

where r_t^{market} is the market excess return and $\mathscr{E}_{n,t}$ is the error. Market return is the value-weighted return of all AMEX, NASDAQ, and NYSE stocks, and the risk-free rate of return is the one-month Treasury bill rate (see Fama & French, 1993).

The portfolios' market betas are estimated with rolling regressions, where the rolling windows are 36 months wide and the estimate of a portfolio's market beta at time t_0 is achieved using monthly data for window $[t_0 - 35, t_0]$. One time series with market betas is estimated for each of the 94 portfolios (i.e., the 25 portfolios formed on size and book-to-market, the 25 portfolios formed on size and momentum, the 32 portfolios formed on size, operating profitability, and investment, and the 12 industry portfolios).

3.3. Data sources

We estimate the parameters in the PSTR model in Eqs. (10)–(11) with nonlinear least squares using monthly data of the variables for the period January 1994 through December 2008 and for the period January 1994 through December 2015. However, because of the rolling regressions in Eq. (17) when estimating the market betas for the portfolios, we also use monthly data of relevant variables for the period February 1991 through December 1993.

The data on the federal funds futures contracts were collected from the database Quandl (see https://www.quandl.com). The U.S. data on the portfolios (i.e., the 6 portfolios formed on size and book-to-market, the 25 portfolios formed on size and book-to-market, the 25 portfolios formed on size and momentum, the 32 portfolios formed on size, operating profitability, and investment, the 12 industry portfolios, and the momentum portfolio) and the market excess returns were downloaded from Kenneth R. French's data library (see http://mba.tuck.dartmouth.edu/pages/faculty/ken.french/data_library.html). The U.S. data on the MPU index were retrieved from the Economic Policy Uncertainty website (see https://www.policyuncertainty.com).

4. Empirical analysis

Table 1 contains 152 FOMC announcement dates during 1994–2015 and the sizes in basis points of the corresponding monetary policy surprises. Most of the surprises were small-sized or even absent, especially during the Federal Reserve's zero interest rate policy during 2009–2015, although there are exceptions. For example, the largest monetary policy surprises occurred in early 2001, when the Federal Reserve's policy was much more expansionary than expected by market participants. However, slightly more than one-third of the Federal Reserve's decisions were expected by market participants, resulting in monetary policy surprises equal to zero. Most of those decisions were made when the strategy by the Federal Reserve was characterized by openness around its policy decisions, which

Table 1
FOMC announcement dates and monetary policy surprises.

Date	Surprise	Date	Surprise	Date	Surprise
1994–02–04	11.67	2003–09–16	0.00	2009–11–04	0.00
1994–03–22	-3.44	2003–10–28	0.00	2009–12–16	-1.03
1994–04–18	10.00	2003–12–09	-0.70	2010–01–27	-1.94
1994–05–17	13.29	2004–01–28	0.00	2010–03–16	0.00
1994–08–16	14.47	2004–03–16	0.00	2010–04–28	0.00
1994–11–15	14.00	2004–05–04	-0.57	2010–06–23	0.00
1995–02–01	5.19	2004–06–30	-1.00	2010–08–10	0.00
1995–07–06	-1.24	2004–08–10	2.21	2010–09–21	0.00
1995–12–19	-10.33	2004–09–21	1.67	2010–11–03	0.28
1996–01–31	-7.00	2004–11–10	0.00	2010–12–14	0.00
1997–03–25	2.58	2004–12–14	0.00	2011–01–26	0.00
1998–09–29	6.00	2005–02–02	0.00	2011–03–15	0.00
1998–10–15	3.88	2005–03–22	0.00	2011–04–27	0.00
1998–11–17	-5.77	2005–05–03	0.00	2011–06–22	-0.94
1999–05–18	-3.58	2005–06–30	0.00	2011–08–09	0.00
1999–06–30	-4.00	2005–08–09	0.00	2011–09–21	0.83
1999–08–24	2.21	2005–09–20	1.50	2011–11–02	0.96
1999–10–05	-4.17	2005–11–01	0.00	2011–12–13	-0.43
1999–11–16	8.57	2005–12–13	0.00	2012–01–25	0.00
1999–12–21	1.55	2006–01–31	0.00	2012–03–13	1.72
2000–02–02	-5.38	2006–03–28	0.00	2012–04–25	0.00
2000–03–21	-3.10	2006–05–10	-0.74	2012–06–20	0.00
2000–05–16	5.17	2006–06–29	-1.50	2012–08–01	-0.15
2000–06–28	-2.00	2006–08–08	-4.04	2012–09–13	0.88
2000–08–22	-1.72	2006–09–20	0.00	2012–10–24	0.00
2000–10–03	0.00	2006–10–25	0.00	2012–12–12	0.00
2000–11–15	0.00	2006–12–12	0.00	2013–01–30	0.00
2000–12–19	5.17	2007–01–31	0.00	2013–03–20	0.00
2001–01–03	-38.20	2007–03–21	0.00	2013–05–01	-0.26
2001–01–31	0.50	2007–05–09	0.00	2013–06–19	1.36
2001–03–20	5.64	2007–06–28	0.00	2013–07–31	0.00
2001–04–18	-42.50	2007–08–07	2.58	2013–09–18	0.00
2001–05–15	-7.75	2007–08–10	0.00	2013–10–30	0.00
2001–06–27	5.00	2007–09–18	-15.00	2013–12–18	0.60
2001–08–21	1.55	2007–10–31	-2.00	2014–01–29	0.00
2001–10–02	-6.95	2007–12–11	0.78	2014–03–19	0.00
2001–11–06	-10.00	2008–01–30	-9.50	2014–04–30	0.00
2001–12–11	0.00	2008–03–18	16.69	2014–06–18	0.00
2002–01–30	1.50	2008–04–30	-5.50	2014–07–30	0.00
2002–03–19	-2.58	2008–06–25	-3.00	2014–09–17	0.00
2002–05–07	0.00	2008–08–05	-0.60	2014–10–29	0.50
2002–06–26	0.00	2008–09–16	5.89	2014–12–17	1.11
2002–08–13	3.44	2008–10–08	-14.15	2015–01–28	0.00
2002–09–24	2.50	2008–10–29	-6.00	2015–03–18	-0.60
2002–11–06	-19.38	2008–12–16	-11.88	2015–04–29	0.00
2002–12–10	0.00	2009–01–28	0.00	2015–06–17	0.00
2003–01–29	0.50	2009–03–18	-0.60	2015–07–29	0.00
2003–03–18	4.77	2009–04–29	-0.50	2015–09–17	-5.77
2003–05–06	3.72	2009–06–24	-2.50	2015–10–28	0.00
2003–06–25	15.00	2009–08–12	-0.82	2015–12–16	2.07
2003–08–12	0.00	2009–09–23	0.00		

Note: Dates (YYYY-MM-DD) for the FOMC announcements and the estimated sizes in basis points of the corresponding monetary policy surprises.

also coincides with its zero interest rate policy during 2009–2015.

The portfolio weights in the construction of the mimicking portfolios and descriptive statistics of the returns on the mimicking portfolios for the periods 1994–2008 and 1994–2015 are presented in Table 2 and Table 3, respectively. Notably, since the mean values of the mimicking portfolio returns are less than 1 basis point in absolute value for both periods, market participants were, on average, able to almost correctly predict the FFR during 1994–2008 and 1994–2015. In addition, the volatilities of monetary policy surprises for both periods are relatively low. Finally, $P\,(F\ \text{statistic}) = 0.000$ for the periods 1994–2008 and 1994–2015, which means that the regressions in the construction of the mimicking portfolios are meaningful.

The main results in the paper are found in Table 4, which shows how monetary policy surprises by the Federal Reserve have affected U.S. stock returns under low and high monetary policy uncertainty during 1994–2008 and 1994–2015, where the estimation

Table 2
Monetary policy surprises proxied with mimicking portfolio returns using data during 1994–2008.

Portfolio weights		
Portfolio	*Unscaled weights* ($\widehat{\alpha}$)	*Scaled weights* ($\widehat{\alpha}/\|\widehat{\alpha}\|$)
Small Growth	-1.974	-0.286
	(1.635)	
Small Neutral	4.227	0.613
	(3.254)	
Small Value	-2.008	-0.291
	(2.960)	
Big Growth	-3.591	-0.521
	(1.477)	
Big Neutral	2.295	0.333
	(1.611)	
Big Value	0.472	0.069
	(1.187)	
Momentum	1.818	0.264
	(0.695)	
Descriptive statistics		
Mean of dependent variable	-0.792	
SD of dependent variable	8.307	
F statistic	8.143	
P (*F* statistic)	0.000	
R^2	0.393	
Adjusted R^2	0.345	

Note: The 6 Fama-French portfolios are the intersections of 2 size portfolios and 3 book-to-market portfolios. The size portfolios are Small (i.e., a relatively low market value of the firm) and Big (i.e., a relatively high market value of the firm). The book-to-market portfolios are Growth (i.e., a relatively low book value of the firm compared with its market value), Neutral, and Value (i.e., a relatively high book value of the firm compared with its market value). Standard errors are in parentheses.

Table 3
Monetary policy surprises proxied with mimicking portfolio returns using data during 1994–2015.

Portfolio weights		
Portfolio	*Unscaled weights* ($\widehat{\alpha}$)	*Scaled weights* ($\widehat{\alpha}/\|\widehat{\alpha}\|$)
Small Growth	-1.944	-0.321
	(1.145)	
Small Neutral	3.464	0.573
	(2.267)	
Small Value	-1.411	-0.233
	(2.021)	
Big Growth	-3.347	-0.553
	(1.028)	
Big Neutral	2.102	0.348
	(1.184)	
Big Value	0.672	0.111
	(0.806)	
Momentum	1.656	0.274
	(0.447)	
Descriptive statistics		
Mean of dependent variable	-0.535	
SD of dependent variable	6.628	
F statistic	11.778	
P (*F* statistic)	0.000	
R^2	0.364	
Adjusted R^2	0.333	

Note: The 6 Fama-French portfolios are the intersections of 2 size portfolios and 3 book-to-market portfolios. The size portfolios are Small (i.e., a relatively low market value of the firm) and Big (i.e., a relatively high market value of the firm). The book-to-market portfolios are Growth (i.e., a relatively low book value of the firm compared with its market value), Neutral, and Value (i.e., a relatively high book value of the firm compared with its market value). Standard errors are in parentheses.

Table 4
PSTR models.

		1994–2008	1994–2015
25 size and book-to-market portfolios	Beta (β_0)	-0.537 (0.363)	-0.561 (0.301)
	Low policy uncertainty (β_1)	-0.869* (0.121)	-1.134* (0.116)
	Difference in policy uncertainty (β_2)	-0.068* (0.028)	0.249* (0.088)
	High policy uncertainty ($\beta_1 + \beta_2$)	-0.938* (0.105)	-0.885* (0.096)
	Slope (γ)	0.193* (0.086)	-0.309 (0.326)
25 size and momentum portfolios	Beta (β_0)	0.257 (0.294)	1.075* (0.257)
	Low policy uncertainty (β_1)	-0.371* (0.100)	-1.346* (0.121)
	Difference in policy uncertainty (β_2)	-1.135* (0.187)	0.244* (0.044)
	High policy uncertainty ($\beta_1 + \beta_2$)	-1.506* (0.162)	-1.102* (0.137)
	Slope (γ)	0.013* (0.003)	0.262* (0.061)
32 size, operating profitability, and investment portfolios	Beta (β_0)	-0.972* (0.348)	-0.733* (0.282)
	Low policy uncertainty (β_1)	-0.878* (0.145)	-1.090 (2.067)
	Difference in policy uncertainty (β_2)	-0.041 (0.154)	0.209 (1.892)
	High policy uncertainty ($\beta_1 + \beta_2$)	-0.919* (0.091)	-0.881* (0.192)
	Slope (γ)	0.690 (6.976)	0.252 (0.586)
12 industry portfolios	Beta (β_0)	-1.251* (0.495)	-0.606 (0.450)
	Low policy uncertainty (β_1)	-0.514* (0.213)	-0.848* (0.194)
	Difference in policy uncertainty (β_2)	-0.211* (0.089)	0.164* (0.045)
	High policy uncertainty ($\beta_1 + \beta_2$)	-0.725* (0.185)	-0.684* (0.174)
	Slope (γ)	0.690* (0.232)	0.381 (0.286)

Note: The models have yearly and monthly time effects. Standard errors are in parentheses, where * indicates statistical significance at the 5 % level.

results for four sets of portfolios (i.e., the 25 size and book-to-market portfolios, the 25 size and momentum portfolios, the 32 size, operating profitability, and investment portfolios, and the 12 industry portfolios) are presented. Yearly and monthly time effects are included in the PSTR model.[2, 3]

We begin with the findings from the PSTR model for the period 1994–2008. First, when monetary policy uncertainty is high, a positive (negative) monetary policy surprise by the Federal Reserve decreases (increases) U.S. stock returns ($\beta_1 + \beta_2$). This statistically significant finding (defined by the five percent level) holds for all four sets of portfolios. Second, positive (negative) monetary policy surprises by the Federal Reserve have a larger negative (positive) effect on U.S. stock returns when there is high monetary policy uncertainty than when the uncertainty is low (β_2). This statistically significant finding holds for three sets of portfolios but not for the 32 size, operating profitability, and investment portfolios. Third, when monetary policy uncertainty is low, a positive (negative) monetary policy surprise by the Federal Reserve decreases (increases) U.S. stock returns (β_1). This statistically significant finding holds for all four sets of portfolios.

We continue with the findings from the PSTR model for the period 1994–2015. First, when monetary policy uncertainty is high, a positive (negative) monetary policy surprise by the Federal Reserve decreases (increases) U.S. stock returns ($\beta_1 + \beta_2$). This statistically significant finding holds for all four sets of portfolios. Second, positive (negative) monetary policy surprises by the Federal Reserve have a larger negative (positive) effect on U.S. stock returns when there is low monetary policy uncertainty than when uncertainty is high (β_2). This statistically significant finding holds for three sets of portfolios but not for the 32 size, operating profitability, and investment portfolios. Third, when monetary policy uncertainty is low, a positive (negative) monetary policy surprise by the Federal Reserve decreases (increases) U.S. stock returns (β_1). This statistically significant finding holds for three sets of portfolios but not for the 32 size, operating profitability, and investment portfolios.

To conclude, using data for the period 1994–2008, we find a negative relationship between surprises in the Federal Reserve's policy and stock returns under both uncertainty regimes but a *less* pronounced relationship between monetary policy surprises and stock returns when uncertainty is low. Moreover, if the data set is extended to also include the period of the zero interest policy by the Federal Reserve during 2009–2015, we again find a negative relationship between monetary policy surprises and stock returns under both uncertainty regimes but a *more* pronounced relationship between the variables when uncertainty is low.

5. Discussion

How do we reconcile the findings in the empirical analysis with the theoretical construct?

Let us begin with the case when data for the period 1994–2008 are used in the empirical analysis. In light of the theoretical

[2] The estimation results for the PSTR models with no time effects, yearly time effects, and monthly time effects are available on request from the authors. The results are similar to those for the PSTR model with yearly and monthly time effects.

[3] Because the PSTR model is a nonlinear model, we must justify the nonlinear effect of monetary policy surprises on stock returns before we can draw any conclusions from the results tabulated in Table 4 regarding how U.S. stock returns have been affected by the Federal Reserve's policy under low and high monetary policy uncertainty. For this reason, four linearity tests (i.e., two *HAC* tests and two *LM* tests) based on the MPU index as the transition variable in the PSTR model are conducted, where we reject linearity in seven of eight cases. The case in which linearity could not be rejected is for the 12 industry portfolios for the period 1994–2015. The estimation results are available on request from the authors.

construct, the conditions in Eqs. (8)–(9) are met, which means that the increase, if any, in the covariance between dividend payments and the discount rate is not large enough when the uncertainty in monetary policy changes from low to high. One reason could be that there are few dramatic episodes during this period, with the effect that the aforementioned covariance is relatively stable. Fig. 1 reveals that there are only two spikes in the MPU index during 1994–2008. The first spike is associated with the September 11 attacks in 2001 when the index reaches the 400 level, and the second spike appears at the onset of the financial crisis when the index increases above the 300 level in September 2008.

Let us continue with the case when data for the period 1994–2015 are used in the empirical analysis, which includes the period of the zero interest policy during 2009–2015. In contrast with the previous case when data for the period 1994–2008 are used, the conditions in Eqs. (6)–(7) in the theoretical construct are now met, which means that the increase in the covariance between dividend payments and the discount rate is large enough when the uncertainty in monetary policy changes from low to high. Why does this change occur in the result? Of course, one reason could be that the covariance between dividend payments and the discount rate is much less stable during 2009–2015 and therefore affects the overall result to such an extent that the conditions in Eqs. (6)–(7) hold instead of Eqs. (8)–(9) in the theoretical construct.

However, a more probable explanation is that because the zero interest rate policy during 2009–2015 was accompanied by nonstandard tools in policymaking, such as quantitative easing, the calculated monetary policy surprises during this timeframe may underestimate the true magnitudes of the surprises. Hence, what appears to be large effects on stock returns caused by small surprises in policymaking during periods of low monetary policy uncertainty might, instead, be large effects on stock returns caused by not-so-small surprises. In other words, the monetary policy-stock return relationship appears to be stronger during periods of low monetary policy uncertainty than what it probably is. Of course, using a similar argument, the monetary policy-stock return relationship also appears to be stronger during periods of high monetary policy uncertainty than what it probably is. However, if the bias in the relationship between the variables is relatively larger when the monetary policy uncertainty is low, then we might conclude that the relationship is more pronounced when uncertainty is low when, in reality, the relationship might be less pronounced.

What can we learn from our study from an investor perspective? If the relationship between monetary policy surprises and stock returns found here holds more generally and is not only a property of the U.S. economy during 1994–2008, which excludes the period of the zero interest rate policy, then it is more important to hedge against unexpected stock market volatility when the uncertainty in monetary policy is high compared to when uncertainty is low. This finding is intuitive but in contrast with the findings in Bauer et al. (2022) and De Pooter et al. (2021), who found that the reactions in the financial markets to surprises in the Federal Reserve's policy were relatively stronger when the uncertainty surrounding the policy was low.

Why does this difference emerge in the findings? First, uncertainty in monetary policy is measured differently in the papers. We use a newspaper-based measure provided by Baker et al. (2016a), whereas Bauer et al. (2022) and De Pooter et al. (2021) use derivatives-based measures of monetary policy uncertainty. It goes without saying that measuring uncertainty is inherently difficult. This fact is exemplified by the many different measures of uncertainty, including measures of monetary policy uncertainty, which exist in the literature (see, e.g., Husted et al., 2020 and Jurado et al., 2015). Thus, the approach taken here when measuring monetary policy uncertainty complements the approaches in Bauer et al. (2022) and De Pooter et al. (2021).

Second, surprises in monetary policy are measured differently in the papers. Our surprise measure utilizes changes in the federal funds futures rate surrounding FOMC announcements, Bauer et al. (2022) utilize changes in the same rate surrounding FOMC announcements and changes in future interest rates according to Eurodollar futures when constructing the surprise measure, and De Pooter et al. (2021) utilize changes in the yield curve surrounding FOMC announcements when constructing the surprise measure. Third, in contrast to our study and the study of Bauer et al. (2022), De Pooter et al. (2021) did not study the monetary policy-stock return relationship but rather the effects on longer-term nominal and real yields of surprises in monetary policy.

Finally, Bauer et al. (2022) and De Pooter et al. (2021) used the event study methodology in their empirical analyses, which is not the case in our paper. This is an important difference that might explain why their findings differ from our findings. Specifically, Bauer et al. (2022), who used daily data and not monthly data as we do, studied the effects of monetary policy surprises on stock returns surrounding FOMC announcements (cf. the 'FOMC uncertainty cycle'), whereas we focus on the monetary policy-stock return relationship at a lower time frequency and not on the days that surround FOMC announcements. Hence, the approach taken here when studying the monetary policy-stock return relationship complements the approach taken in Bauer et al. (2022).

References

Baker, S. R., Bloom, N., & Davis, S. J. (2016a). Economic Policy Uncertainty. See ⟨http://www.policyuncertainty.com⟩.
Baker, S. R., Bloom, N., & Davis, S. J. (2016b). Measuring economic policy uncertainty. *Quarterly Journal of Economics, 131*, 1593–1636.
Basistha, A., & Kurov, A. (2008). Macroeconomic cycles and the stock market's reaction to monetary policy. *Journal of Banking and Finance, 32*, 2606–2616.
Bask, M. (2010). Measuring potential market risk. *Journal of Financial Stability, 6*, 180–186.
Bask, M., & de Luna, X. (2002). Characterizing the degree of stability of non-linear dynamic models. *Studies in Nonlinear Dynamics and Econometrics, 6*(1), Article 3.
Bask, M., & de Luna, X. (2005). EMU and the stability and volatility of foreign exchange: some empirical evidence. *Chaos, Solitons and Fractals, 25*, 737–750.
Bask, M., & Widerberg, A. (2009). Market structure and the stability and volatility of electricity prices. *Energy Economics, 31*, 278–288.
Bask, M., & Widerberg, A. (2012). Actual and potential market risks during the stock market turmoil 2007-2008. *Applied Financial Economics, 22*, 339–349.
Bauer, M. D., Lakdawala, A., & Mueller, P. (2022). Market-based monetary policy uncertainty. *Economic Journal, 132*, 1290–1308.
Bernanke, B. S., & Kuttner, K. N. (2005). What explains the stock market's reaction to Federal Reserve policy? *Journal of Finance, 60*, 1221–1257.
Black, F. (1987). *Business Cycles and Equilibrium*. Cambridge: MA, and Oxford: Basil Blackwell.
Bomfim, A. N. (2003). Pre-announcement effects, news effects, and volatility: monetary policy and the stock market. *Journal of Banking and Finance, 27*, 133–151.
Carhart, M. M. (1997). On persistence in mutual fund performance. *Journal of Finance, 52*, 57–82.
Chava, S., & Hsu, A. (2020). Financial constraints, monetary policy shocks, and the cross-section of equity returns. *Review of Financial Studies, 33*, 4367–4402.
Chen, S.-S. (2007). Does monetary policy have asymmetric effects on stock returns? *Journal of Money, Credit and Banking, 39*, 667–688.

De Pooter, M., Favara, G., Modugno, M., & Wu, J. (2021). Monetary policy uncertainty and monetary policy surprises. *Journal of International Money and Finance, 112*, Article 102323.
Ehrmann, M., & Fratzscher, M. (2004). Taking stock: monetary policy transmission to equity markets. *Journal of Money, Credit and Banking, 36*, 719–737.
Fama, E. F., & French, K. R. (1988). Dividend yields and expected stock returns. *Journal of Financial Economics, 22*, 3–25.
Fama, E. F., & French, K. R. (1993). Common risk factors in the returns on stocks and bonds. *Journal of Financial Economics, 33*, 3–56.
Fama, E. F., & French, K. R. (1997). Industry costs of equity. *Journal of Financial Economics, 43*, 153–193.
Fama, E. F., & French, K. R. (2015). A five-factor asset pricing model. *Journal of Financial Economics, 116*, 1–22.
González, A., Teräsvirta, T., van Dijk, D., & Yang, Y. (2017). Panel Smooth Transition Regression Models. Mimeo.
Guo, H. (2004). Stock prices, firm size, and changes in the federal funds rate target. *Quarterly Review of Economics and Finance, 44*, 487–507.
Hansen, B. E. (1999). Threshold effects in non-dynamic panels: estimation, testing, and inference. *Journal of Econometrics, 93*, 345–368.
Husted, L., Rogers, J., & Sun, B. (2020). Monetary policy uncertainty. *Journal of Monetary Economics, 115*, 20–36.
Ippolito, F., Ozdagli, A. K., & Perez-Orive, A. (2018). The transmission of monetary policy through bank lending: the floating rate channel. *Journal of Monetary Economics, 95*, 49–71.
Jensen, G. R., & Mercer, J. M. (2002). Monetary policy and the cross-section of expected stock returns. *Journal of Financial Research, 25*, 125–139.
Jensen, G. R., Mercer, J. M., & Johnson, R. R. (1996). Business conditions, monetary policy, and expected security returns. *Journal of Financial Economics, 40*, 213–237.
Jurado, K., Ludvigson, S. C., & Ng, S. (2015). Measuring uncertainty. *American Economic Review, 105*, 1177–1216.
Kuttner, K. N. (2001). Monetary policy surprises and interest rates: evidence from the fed funds futures market. *Journal of Monetary Economics, 47*, 523–544.
Lobo, B. J. (2000). Asymmetric effects of interest rate changes on stock prices. *Financial Review, 35*, 125–144.
Lobo, B. J. (2002). Interest rate surprises and stock prices. *Financial Review, 37*, 73–92.
Patelis, A. D. (1997). Stock return predictability and the role of monetary policy. *Journal of Finance, 52*, 1951–1972.
Pukthuanthong, K., Roll, R., Wang, J., & Zhang, T. (2020). A Tool Kit for Factor-Mimicking Portfolios. Mimeo.
Rozeff, M. S. (1974). Money and stock prices: market efficiency and the lag in effect of monetary policy. *Journal of Financial Economics, 1*, 245–302.
Teräsvirta, T. (1994). Specification, estimation, and evaluation of smooth transition autoregressive models. *Journal of the American Statistical Association, 89*, 208–218.
Teräsvirta, T., Tjøstheim, D., & Granger, C. W. J. (2010). *Modelling Nonlinear Economic Time Series*. Oxford: Oxford University Press.
Thorbecke, W. (1997). On stock market returns and monetary policy. *Journal of Finance, 52*, 635–654.
Vassalou, M. (2003). News related to future GDP growth as a risk factor in equity returns. *Journal of Financial Economics, 68*, 47–73.