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ABSTRACT

Monetary Policy Uncertainty and the Stock Market*

We study the relationship between inflation and stock returns focusing on the signalling content of inflation. Investors use inflation to learn about the stance of the monetary policy. Depending on investors' beliefs, a change in consumption prices has different effects on the risk premium. A change in consumption prices that confirms investors' beliefs reduces stock risk premia, while a change that contradicts them increases risk premia. This may generate a negative correlation between returns and inflation that explains the Fisher puzzle. We model this intuition and test its implication on US data. We construct a market-based proxy of monetary policy uncertainty, we show that it is priced and that, by conditioning on it, the Fisher puzzle disappears.

JEL Classification: G11, G12 and G14
Keywords: asset pricing, learning risk, monetary policy uncertainty and risk factors

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1 Introduction

The stance of monetary policy is a crucial variable for investors taking a short/medium term perspective. Indeed, the effects of inflation on future cash flows largely depend on the way monetary authorities react to it. In the case of a non accommodative monetary policy, higher inflation induces a monetary squeeze which, in turn, negatively affects future growth, leading to lower cash flows and lower stock prices. On the contrary, in the case of an accommodative monetary policy, inflation is simply an indicator of an accelerating cycle and signals higher growth prospects, leading to higher cash flows and higher stock prices.

Investors do not know the stance of monetary policy. This is due to the genuine uncertainty arising from the debate within the FOMC and to the fact that the Fed itself works to preserve uncertainty about its policy in order to increase its effectiveness. "Greenspan & Co.'s rhetorical gymnastics suggest that the "unanimous" policy agreement came following some dissent and heavy debate...In a roundabout way, the Fed has maximized its policy options. Through their cryptic reading on the economy and deflation, the central bankers are seeking to retain as much flexibility as possible." (BusinessWeek, May, 2003). That is, "the discretionary component of monetary policy is driven by exogenous shocks to the preference of the monetary authority, perhaps due to stochastic shifts in the relative weight given to unemployment and inflation. These shifts could reflect shocks to the preferences of the members of the Federal Open Market Committee, or to the weights by which their views are aggregated. A change in weights may reflect shifts in the political power of individual committee members or in the factions they represent." (Christiano *et al.,* 1999).

The lack of transparency, by generating uncertainty, affects investors' decisions and therefore stock prices. To reduce this uncertainty, the market uses any available signal that allows it to learn about the stance of monetary policy. Inflation, by offering the investors an opportunity to study the central banker's reaction, provides such an information. Inflation may reinforce already defined beliefs of a particular type of monetary policy as well as challenge the beliefs of another type of monetary policy. In the former case, inflation, by confirming investors' beliefs, reduces informational uncertainty and therefore the risk premium and the required rate of return. If this reduction in returns is high enough, it may induce a "puzzlingly" negative correlation between inflation and stock returns. This can help to explain the so-called Fisher "puzzle", that is the empirical observation that expected inflation and stock returns fail to move together in the way predicated by theory and actually move in the opposite direction.

In this paper we explicitly link stock prices to monetary policy uncertainty. We makes two contributions. We show that uncertainty about monetary policy is priced and that this helps explain the Fisher puzzle. We start by laying out a theoretical model that directly relates the effects of inflation on stock returns to the way investors learn about the stance of monetary policy. We assume monetary policy to be an exogenous process and study how investors react to the uncertainty generated by the unobservability of the monetary authority's preferences. We then show how this uncertainty affects stock prices. Inflation is one of the signals investors use to learn the stance of monetary policy. The learning process generates uncertainty that increases the risk premium. We prove that, depending on the equilibrium beliefs of the investors on the stance of monetary policy, a change in consumption prices has different effects on the risk premium. A change in consumption prices that confirms investors beliefs leads to a reduction in risk premium, while a change that contradicts investors beliefs increases risk premia.

We argue that this can explain the Fisher puzzle. We show that, if the signal embedded in inflation is consistent with investors' beliefs, an increase of inflation may reduce uncertainty and therefore risk premia, thus leading to a negative correlation between inflation and returns. By realistically calibrating the model with US data, we show that the reduction in risk premia during the periods when investors beliefs are confirmed by the change in consumption prices is sufficient to generate a negative correlation between returns and inflation.

We then test the restrictions of the model, by using US data for the period 1965-1998. We construct a market-based proxy of monetary policy uncertainty and we show that it is priced. Moreover, if we proper condition on the fundamental and monetary policy uncertainty, the Fisher puzzle disappears. The empirical results largely support our hypothesis, showing that uncertainty about monetary policy is indeed priced.

The paper is organized as follows. In the next section, we provide a brief survey of the literature. In Section 3, we lay out a simple model of the interaction of monetary policy uncertainty on stock prices. Section 4 reports the main empirical implications. Section 5 describes the construction of a proxy for monetary policy uncertainty. Section 6 provides the main empirical findings. A brief conclusion follows.

2 The literature

The relationship between fundamental uncertainty and monetary policy uncertainty and their impact on asset prices have scarcely been directly analyzed. Monetary economists have extensively analyzed monetary uncertainty, but only in order to assess the role played by transparency and credibility in the conduct of monetary policy (Barro and Gordon, 1983, Cuckierman and Meltzer, 1986, Goodfriend, 1986, Kydland and Prescott, 1977, Rogoff, 1989, Stein, 1989, Svensson, 1999). Credibility is either assumed constant (Barro and Gordon, 1983, Kydland and Prescott, 1977) or modelled as idiosyncratic unobservable shifts (Cuckierman and Meltzer, 1986). In the latter case, transparency, credibility and reputation are derived in models where the characteristics of the monetary authority are unobservable to the private sector and inferred by observing the policy outcome. In this context, the uncertainty related to the type of monetary policy (i.e. accommodative or non-accommodative) is relevant for its impact on the effectiveness of the conduct of the monetary policy itself. For example, Faust and Svensson (1997) show how a low-credibility bank may optimally conduct a more inflationary policy than a high-credibility bank. However, no direct link is explicitly formulated between monetary policy uncertainty and asset prices.

On the other hand, financial economists have mostly focused on dividend uncertainty and touched upon inflation uncertainty, but very rarely directly investigated the impact of monetary policy uncertainty on asset prices. More strikingly, even models that properly account for the relationship between inflation and stock returns are rare. In a general equilibrium context, Stulz (1986) shows that an increase in expected inflation, by reducing real wealth, induces investors to choose a portfolio of risky assets with a lower risk-return profile. This generates negative correlation between stock returns and inflation.

The most studied feature of the relationship between inflation and asset prices has been the so-called "Fisher puzzle", that is the fact that, contrary to conventional wisdom, common stocks fail to fully insure against inflation and, more importantly, move in the wrong direction in the face of an acceleration in prices. In particular, Fama and Schwert (1977) show a negative correlation between real and nominal stock returns (and excess returns) and inflation. The fact that their specification is neither a structural nor a reduced-form one implies that their results may be due to spurious correlations caused by the omission of relevant variables. Indeed, Fama (1981) himself claims that the anomalous return-expected inflation relation may be due to errors in the specification. His hypothesis is that anticipated future changes in the level of economic activity affect inflation and stock returns in opposite directions: the failure to condition on expectations of future output growth induces a spurious negative correlation.[1]

[1]In particular, when a proxy for future real activity is included as a regressor, expected inflation loses most of its explanatory power and becomes insignificant. A similar objection has been raised more recently by Groenewold *et al.* (1997). They show that, in a macroeconometric model the reduced-form equation for common stock returns features as regressors all the exogenous variables (government consumption, tax rates and foreign variables). When the proper theoretical restrictions are imposed and the whole structure of the model is taken into account, the sign of the effect of expected inflation is not univocally determined and depends on the specific value of the coefficients

A modified version of Fama's argument is provided by Geske and Roll (1983), who argue that the direction of causality goes from stock returns to inflation expectations and not the reverse. Given that the government derives most of its revenues from income taxes, when stock prices react in response to anticipated changes of business conditions, income taxes and government revenues move in the same direction. If public expenditures do not adjust accordingly, fluctuations in revenues are reflected in higher deficits, which will then be financed partly by printing money. As investors foresee a future monetization of the debt, inflation expectations rise. Thus alterations in stock prices caused by changes in anticipated economic conditions will be negatively correlated with changes in both expected and unexpected inflation.

More recently, Boudoukh, Richardson and Whitelaw (1994) investigate the cross-sectional implications of the Fisher relation and find that stock returns of non-cyclical industries tend to covary positively with expected inflation, while the reverse holds for cyclical industries.

A third strand of literature has tried to explain the relationship between stock returns and inflation by directly focusing on the role played by switches in monetary policy regimes. Evans and Lewis (1995), for example, find that during the post-war period the inflation process underwent some significant shifts. Boudoukh and Richardson (1993) find that over a very long horizon the puzzle disappears.

Kaul (1990) argues that a counter-cyclical money supply is responsible for the negative correlation between inflation and asset returns and a different economic scenario, namely a pro-cyclical response of the money supply to output fluctuations, would lead to insignificant or even positive correlations. Along the same line, Söderlind (1999) shows that, if the central bank attempts to stabilize output fluctuations, nominal returns and inflation should move in parallel since the monetary authority keeps real interest rates fixed in order to cushion shocks to economic activity. Conversely, if the central bank is mostly concerned with inflation, movements in nominal rates are, to a large extent, likely to reflect changes in real rates.[2] However, neither of these models accounts for investors' learning about the type of monetary policy and the ensuing uncertainty that the learning process generates.

In general, the three strands of literature have not focused on the way investors react to the informational uncertainty concerning the stance of monetary policy, that is, the way that financial markets use inflation as a signal to price the uncertainty resulting from the type of monetary regime. Our goal is to contribute by providing a framework

of the model.

[2]More recently, Thorbecke (1997) has attempted to measure the influence of monetary policy on stock returns, finding that though such influence is quite sizeable, it is not big enough to explain the predictive power of other financial variables (e.g. dividend yield) or to account for the predictable volatility in excess returns.

that models and links fundamental uncertainty and monetary policy uncertainty.

3 A simple model

We start form the fact that the literature in general agrees that, while the actions of the monetary policy are rather explicit, their interpretation is not immediate or direct. Indeed, any action has to be considered in terms of macroeconomic developments and depends on the overall monetary objectives. Investors do not have access to the same information set of the monetary authority and also fail to know monetary objectives in detail and are therefore trying to learn about them. We will focus on the process through which investors try to learn the uncertainty about monetary policy.

We will not try to describe the behavior of the monetary authority. We rather assume monetary policy to be an exogenous process and focuses on how the reaction of investors to the uncertainty generated by the unobservability of central bank's preferences affects asset prices. This reduced form specification is meant to provide testable restrictions to be brought to the data. The model builds on David (1987), Veronesi (1999) and David and Veronesi (2000) and is based on an exchange economy with a single consumption good and one single risky asset.

The model and the empirical estimation are based on a Markov switching framework. As stressed by Sims (1982) and Cooley et al. (1984), it is at least doubtful whether changes in the policy framework should be characterized as permanent changes in the parameters of a reaction function. In fact, genuine changes in regime are rare events since agents, knowing the menu of choices available to the policy makers, form their expectations on the basis of past experience which take into account all possible outcomes. In other words, they have a probability distribution ranging over all possible policy rules and they use it to forecast the behavior of the policy makers. In this perspective, "regime" changes represent neither rare events nor abnormal policy shifts, but are instead better viewed as variations in central bank policy which cannot be accounted for as a reaction to the state of the economy. These changes might reflect *exogenous shocks to the preferences of the monetary authority, due perhaps to stochastic shifts in the relative weights given to different policy objectives, or may be induced by changes in the composition of the monetary policy committee.* Alternatively, they might be caused by incomplete unobservability of the state of the economy at the time decisions are to be taken (Christiano *et al.*,1999).

In this framework, a Markov switching framework is flexible enough to cover both once-and-for-all structural changes as well as policies which are set period-by-period. Any intermediate case can be obtained by appropriately choosing the parameters of the transition matrix. Given that our focus is the reaction of the investors to monetary policy uncertainty, the description of the behavior of the central bank is necessarily very stylized. One possible objection is that there is really nothing in the model that differentiates it from a standard-switching model for stochastic, payoff-relevant variables. We will address this issue in the following sections, where we will directly empirically identify the sources of the switching regimes in monetary policy regimes.

Monetary policy regimes.

Monetary policy can be either accommodative or non-accommodative. Its stance (θ_t) follows a Poisson process with two values: a and b. In the former case ($a > 0$) the monetary policy is accommodative. In the latter case ($b < 0$), the monetary policy is tight. The probability transition matrix between time t and time $t + dt$ is:

$$\begin{array}{c|cc} & \mathbf{a} & \mathbf{b} \\ \hline \mathbf{a} & 1-\lambda dt & \lambda dt \\ \mathbf{b} & \lambda dt & 1-\lambda dt \end{array} \tag{1}$$

For simplicity, we assume that $a = 1$ and $b = -1$. This framework is meant to capture the fact that, while the actions of the monetary policy are rather explicit, their interpretation is not immediate or direct. Indeed, investors do not have access to the same information set of the monetary authority and do not know the monetary objectives in detail. Therefore, they have to infer them by using the available information and signals (i.e., consumption and stock prices).

Given that our focus is the reaction of the investors to monetary policy uncertainty, the description of the behavior of the central bank is necessarily very stylized. One may argue that there is nothing in the model that differentiates it from a standard-switching model for stochastic, payoff-relevant variables. We will address this issue in Section 4.1, where we will directly empirically identify the sources of the switching regimes in monetary policy regimes.

Dividend uncertainty.

Real dividends follow a geometric Brownian motion:

$$\frac{dD_t}{D_t} = [\mu_D + \beta\theta_t]\, dt + \mathbf{b}_D d\mathbf{z}_t, \tag{2}$$

where $\mathbf{b}_D = (\sigma_D, 0, 0)'$ and $\mathbf{z}_t$ is a vector of Wiener processes we will define below. μ_D is the long term productivity level and β is the sensitivity of real dividends to monetary policy. We assume it to be positive. A tight monetary policy reduces the real growth of the economy ($\theta_t < 0$), while an expansionary monetary policy ($\theta_t > 0$) raises it. That is, monetary policy has a real impact in the short run. Unconditionally, the long run impact on the economy is equal to zero.

Inflation uncertainty.

Following Stulz (1986), we directly define the price level of the single consumption good in the economy (p_t) and assume it to follows,

$$\frac{dp_t}{p_t} = [\mu_p + \delta\theta_t]\, dt + \mathbf{b}_p d\mathbf{z}_t, \tag{3}$$

where $\mathbf{b}_p = (0, \sigma_p, 0)'$. μ_p is the long run inflation level and δ is sensitivity of the price level to the stance of monetary policy. We assume it to be positive. β and δ characterize the type of economy and define how costly it is for the central bank to tame inflation. If β is high and δ is low, the deflationary impact of curbing inflation is strong, while if β is low and δ is high, the central bank can reduce inflation without a big output loss.

Our modelization of the transmission of monetary policy is consistent with the prototype New Keynesian model of monetary policy (Clarida, Gali and Gertler, 1999) where the impact of monetary policy on real and nominal variables is direct and immediate. Also, it is important to note, while monetary policy affects GDP and price growth, the model does not imply that monetary policy is the only responsible for the booms or recessions.

Investors' behavior.

The representative investor has a power utility function $u(t, C_t) = e^{-\phi t}\frac{C_t^{1-\rho}-1}{1-\rho}$, where C_t is the consumption level, ρ is the degree of risk aversion and ϕ is the discount rate. The investor may invest in a risky asset (stock) and in a riskless asset (bond) that delivers a nominal riskless rate equal to r_t^n. The investor has two sources of income: dividends and endowment (Berk, Green and Naik, 1999, Cecchetti, Lam and Mark, 1993, Campbell and Cochrane, 1999, and Barberis, Huang and Santos,2001). We define their aggregate value as total real consumption (David and Veronesi, 2000). It follows:

$$\frac{dC_t}{C_t} = (\mu_c + \gamma\theta_t)dt + \mathbf{b}_c d\mathbf{z}_t, \tag{4}$$

where μ_c is the long term mean consumption growth, γ is the impact of monetary policy on it and $\mathbf{b}_c = (\sigma_{c_D}, 0, \sigma_e)'$and $\mathbf{z}_t$ is the vector of the different sources of uncertainty (i.e. dividend uncertainty, price uncertainty and endowment uncertainty, or $\mathbf{z} = (z_{D,t},$ $z_{p,t},$ $z_{e,t})'$). We assume that the three sources of uncertainty are not correlated. The unconditional expectation is that monetary policy does not affect consumption growth in the long run. It is worth noting that we assume that the impact of monetary policy on consumption is different from the one on dividends and that $\gamma \leq \beta$.

The investor has three signals available (D_t, p_t and C_t) and four sources of uncertainty. He learns about the value of θ_t.[3]

[3]Given the assumption of a single-representative agent, the observation of dividends provides the

Theorem 1 *The expected value of the nominal excess stock return over the riskless asset (R_t) is:*

$$E[\frac{dS_t^n}{S_t^n} + \frac{D_t^n}{S_t^n} - r_t^n dt]/dt = \Gamma_t + \Theta_t + \Phi_t = F_t + \Phi_t, \tag{5}$$

where $\Gamma_t = \mu_D - \beta(1-2\pi_{a,t}) - \phi - \rho\mu_c + \frac{1}{2}\rho(\rho+1)\mathbf{b}_c\mathbf{b}_c'$, $\Theta_t = (1-2\pi_{a,t})\left[\frac{2(\beta-\rho\gamma)\lambda}{\Psi_t} + \gamma\rho\right]$, $\Phi_t = \pi_{a,t}(1-\pi_{a,t})\frac{4(\beta-\rho\gamma)}{\Psi_t}(\beta\Omega_t + \delta - \gamma)$, *and the values of* Ω_t *and* Ψ_t *are defined in the Appendix (proof in the Appendix).*

Γ_t is made of the conditional expected real dividend return ($E_t[\frac{dD_t}{D_t}]/dt = \mu_D - \beta(1-2\pi_{a,t})$) and of some adjustment for consumption growth and risk. Θ_t represents the risk of inflation and in particular of the fact that the the central bank, in order to curb inflation, reduces output. These first two terms represent the part of the risk due to both the real sources of income (dividend and endowment or consumption) and inflation. We aggregate them and define $F_t = \Gamma_t + \Theta_t$ as the "fundamental" component of the risk premium. Finally, the term Φ_t captures the learning uncertainty about the stance of monetary policy or monetary policy uncertainty. It is highest at $\pi_{a,t} = 0.5$ and lowest at $\pi_{a,t} = 0$ or $\pi_{a,t} = 1$.

Equation 5 provides two key insights: one about pricing and the other about the Fisher puzzle. It also provides us with a way of directly quantifying the degree of monetary policy uncertainty. In the next section we will examine these implications separately. But before, we define expected inflation. This is:

$$E\left[\frac{dp_t}{p_t}\right]/dt = [\mu_p + (2\pi_{a,t} - 1)\delta], \tag{6}$$

This equations shows that there is a direct mapping between expected inflation ($E_t[dp_t/p_t]$) and the beliefs on the stance of monetary policy ($\pi_{a,t}$). This implies that we can alternative use one as a direct proxy for the other.[4]

4 The role of monetary policy uncertainty

4.1 Pricing implications

Equation 5 shows that the risk premium can be decomposed into a component due to "fundamental uncertainty" (F_t) and one due to "monetary policy uncertainty" or

same information as the observation of asset prices or returns (i.e., stock and bond rates).

[4]In particular, from a simple application of the Implicit Function Theorem, we can see that there is a direct relationship between the impact of expected inflation on stock returns and the impact of a change in the beliefs about the type of monetary regime (π_a) on stock returns. That is, $E_t\left\{\frac{dR}{dE[\frac{dp}{p}]} = \frac{1}{2\delta}\frac{dR}{d\pi_a}\right\}$.

simply "policy uncertainty" ($\mathit{\Phi}_t$). The component due to fundamental uncertainty is a function of both the uncertainty related to the real fundamentals (dividend and endowment) and the uncertainty related to inflation. The component related to the degree of monetary policy uncertainty (Φ_t) is a function of the beliefs of the investors of the stance of monetary policy ($\pi_{a,t}$) or, according to equation 6, of inflation.

A graphical representation of the relationship between risk premia and investors' beliefs of the monetary regime (or expected inflation) is reported in Figures 1 and 2. We graph the risk premium for different values of β, δ, $\pi_{a,t}$ and percentage share of dividends out of aggregate consumption. The graphs are based on parameters derived by calibrating the model to actual data for the period January 1965 - December 1998. Details of the calibration are provided in the Appendix. The risk premium has a hump-shaped relationship with respect to such beliefs. When $\pi_{a,t} < 0.5$, that is when the market is confident that the monetary policy is accommodative, an increase in inflation (i.e., change in $\pi_{a,t}$ as from equation 6) raises the risk premium. Indeed, an increase in inflation raises the uncertainty of an investor who believes the central bank to be non-accommodative. In contrast, when $\pi_{a,t} > 0.5$, that is when the market is confident that the monetary policy is accommodative, an increase in inflation reduces the risk premium. An increase in inflation confirms the priors of an investor who believes the central bank to be accommodative and therefore reduces his monetary policy uncertainty.

Exhibit 1: Effects of expected inflation on risk premia

	Perceived Monetary Policy Regime	
	Non-accommodative ($\pi_a < 0.5$)	Accommodative ($\pi_a > 0.5$)
Expected inflation increases	Positive	Negative
Expected inflation decreases	Negative	Positive

Therefore, both an increase of inflation when investors believe that the monetary policy is tight (first quadrant in Exhibit 1) and a reduction of inflation when investors believe that the monetary policy is expansionary (fourth quadrant in Exhibit 1) increase the risk premium. On the contrary, both an increase of inflation when investors believe that the monetary policy is expansionary (second quadrant in Exhibit 1) and a reduction of inflation when investors believe that the monetary policy is tight (third quadrant in Exhibit 1) reduce the risk premium. The points on the diagonal represent outcomes where a change in expected prices ($Infl_t^e$) moves against investors' prior beliefs. By increasing uncertainty, it raises the risk premium. Conversely, the off-diagonal points represent outcomes where a change in expected prices is aligned with investors' prior beliefs. By further tightening investors' posteriors this reduces uncertainty and decreases the risk premium.

The intuition is that a change in consumption prices provides the investors with an opportunity to study how the central bank reacts and to infer the stance of monetary policy. Low inflation can reinforce already defined beliefs of a non-accommodative policy, as well as disprove the beliefs of an accommodative one. If the signal reinforces investors' beliefs, it will reduce risk premia. In particular, both an increase of inflation when investors believe that the monetary policy is tight as well as a reduction of inflation when investors believe that the monetary policy is expansionary increase the risk premium. Vice-versa, an increase of inflation when investors believe that the monetary policy is accommodative as well as a reduction of inflation when investors believe that the monetary policy is tight reduce the risk premium.

Equation 5 provides a directly testable restriction. If we use the pricing kernel representation, stock excess returns can be expressed as:

$$E[R_{jt}|\Omega_{t-1}] = \sum_{i=1}^{L} \lambda_{i,t-1} cov[R_{jt}, \Upsilon_{it}|\Omega_{t-1}], \tag{7}$$

where R_{jt} is the excess rate of return on the *jth* stock at time *t,* λ_i is the price of risk and Υ_{it} is the return on the portfolio that proxies for the *ith* factor of the economy, for $i = 1, ..., L$. In a conditional specification (Dumas and Solnik, 1995), Ω_{t-1} is the information set investors use in order to make their portfolio decision. We will consider two cases: in the unrestricted case, there are 4 factors (i.e., $L = 4$): the 3 Fama and French factors (FF henceforth) that proxy for the fundamentals (i.e., F_t) and the factor proxying for monetary policy uncertainty (i.e., Φ_t). In the restricted case, we consider only the 3 FF factors.

If we define M_t as the marginal rate of substitution between returns at t and at $t-1$, the first order conditions of the portfolio choice problem can be expressed as:

$$E[M_t(1+\rho_{t-1})|\Omega_{t-1}] = 1 \text{ and } E[M_t R_{jt}|\Omega_{t-1}] = 0. \tag{8}$$

where ρ_{t-1} is the conditionally riskless rate of interest at time *t-1.* By substituting equation 7 into equation 8, we have that M_t is:

$$M_t = [1 - \lambda_{o,t-1} - \sum_{i=1}^{L} \lambda_{it-1}\Upsilon_{it}]/(1+\rho_{t-1}). \tag{9}$$

Equation 8 allows us to proceed to define the orthogonality conditions of the econometric specification. We use a set of instrumental variables $\mathbf{Z}_{t-1}$, in order to proxy for the information set Ω_{t-1}. $\mathbf{Z}_{t-1}$ represent the state variables investors condition their portfolio decision on. We assume that the price of risk (λ) is linearly related to such state variables, according to:

$$\lambda_{o,t-1} = -\mathbf{Z}_{t-1}\boldsymbol{\delta} \text{ and } \lambda_{i,t-1} = \mathbf{Z}_{t-1}\boldsymbol{\phi}_i, \tag{10}$$

where $\boldsymbol{\delta}$ and $\boldsymbol{\phi}s$ are time-invariant vectors of weights. If we define the innovation u_t in the marginal rate of substitution as:

$$u_t = 1 - M_t(1 + \rho_{t-1}), \tag{11}$$

or, using equation 9:

$$u_t = -\mathbf{Z}_{t-1}\boldsymbol{\delta} + \sum_{i=1}^{L} \mathbf{Z}_{t-1}\boldsymbol{\phi}_i \Upsilon_{it}, \tag{12}$$

and we define $h_{jt} = r_{jt} - r_{jt}u_t$, we can rewrite the pricing conditions of equation 8 in terms of the orthogonality conditions:

$$E[u_t|\Omega_{t-1}] = 0 \tag{13}$$
$$E[\mathbf{h}_t|\Omega_{t-1}] = 0, \tag{14}$$

where $\mathbf{h}_t$ is the vector that contains the h_{jt} stacked for all the considered portfolios. Equations 13 and 14 provide the set of orthogonality conditions. In particular, if we define the vector of residuals $\boldsymbol{\varepsilon}_t = (u_t, \mathbf{h}_t)$, we can rewrite the system of equations 13 and 14 as:

$$E[\boldsymbol{\varepsilon}_t|\mathbf{Z}_{t-1}] = 0, \tag{15}$$

or its sample version:

$$\mathbf{Z}'\boldsymbol{\varepsilon} = 0, \tag{16}$$

where Z is the TxI matrix containing the sample values of the instruments, ε is the *Tx(1+m)* matrix containing the residuals, T the sample size, I the number of instruments and m the number of portfolios used to test the model (25 in the book-to-market and size specification and 17 in the industry specification).

Equation 16 allows us to test whether the model we are using is correct and whether the additional factor we are considering is relevant and priced. If the factors are priced, equations 13 and 14 must hold and the value of the quadratic form of equation 16 must be asymptotically distributed as a χ^2.

Also, from equations 9 and 10, we can derive the pricing power of the monetary policy factor by directly looking at the significance of the vector of coefficients $\boldsymbol{\phi}_{\Phi_t}$, where $\lambda_{\Phi_t,t-1} = \mathbf{Z}_{t-1}\boldsymbol{\phi}_{\Phi_t}$ for monetary policy uncertainty. If monetary policy uncertainty is priced at least some of the coefficients of $\boldsymbol{\phi}_{\Phi_t}$ should be significant. Testing for the significance of $\lambda_{\Phi_t,t-1}$ (ϕ_{Φ_t}) is the appropriate strategy when the risk factors are correlated. Indeed, the λs are the multiple regression coefficients of M_t on $[F_t, \Phi_t]$ and capture whether one factor is marginally useful in pricing assets, given the presence of the other factors (Cochrane, 2000).

4.2 New Perspective on the Fisher Puzzle

Equation 5 has direct implications for the Fisher puzzle. While the Fisher relationship requires that:

$$Corr\left[R_t, Infl_t^e\right] = 0, \tag{17}$$

the "Fisher puzzle" is the empirical finding that:

$$Corr\left[R_t, Infl_t^e\right] < 0. \tag{18}$$

On the basis of our working hypothesis, this negative correlation can now be explained in terms of the monetary policy risk premium. *If a change in consumption prices (inflation) reduces the part of risk premium due to monetary policy uncertainty enough, the net effect can be a negative correlation between inflation and stocks returns.*

Unconditionally, the sign of the correlation between expected inflation ($Infl^e$) and risk premium depends on the relative frequency of periods when monetary policy is perceived as non-accommodative and on the size of the component of the risk premium due to policy uncertainty as opposed to the component due to fundamental uncertainty. The correlation between an increase in consumption prices and risk premia is positive in periods of non accommodative monetary policy and negative during periods of accommodative monetary policy. The fact that monetary policy has been perceived as accommodative for most of the observed sample (Figure 3) may justify the negative relationship found in the literature. This is also consistent with the fact that on a longer sample the Fisher relationship seems to hold (Boudoukh and Richardson, 1993).

Conditionally, if we properly control for fundamental uncertainty (F_t) and monetary policy uncertainty (Φ_t), we should be able to get back to the expected zero correlation between inflation and stock *excess* returns. A directly testable restriction is therefore:

$$Corr\left[\widehat{R_t}, Infl_t^e\right] = 0, \tag{19}$$

where $\widehat{R_t}$ is the risk premium in a specification *where we properly control for the fundamental and monetary policy uncertainty factors as from equation 5.* As a strategy, we will therefore verify whether unconditionally we find the Fisher puzzle in our sample and whether, after conditioning on the fundamental and policy uncertainty factors, the Fisher puzzle disappears.

5 A proxy for monetary policy uncertainty

Equation 5 also suggests a way to construct a measure of monetary policy uncertainty: $I = \pi_a(1 - \pi_a)$. This indicator peaks ($I_t = 0.25$) when investors are highly uncertain about what the regime of monetary policy (i.e. $\pi_{a,t} = 0.5$), and hits the floor ($I_t = 0$) when investors have a well defined belief about it (i.e., $\pi_{a,t} = 0$ or $\pi_{a,t} = 1$). To implement it, we need to find suitable proxies for π_a. We could adopt two approaches: either use extra-sample evidence or try to derive it directly from financial market data. The former approach is limited by the lack of a good proxy. One possibility would be to use the dispersion of forecasts contained in the surveys of professional forecasters and economists. For example, the Livingston Survey, the ASA-NBER Survey of Professional Forecasters and the University of Michigan Inflation Expectations contain information about expected inflation. The former two also have some information about the dispersion of forecasts across analysts. However, the Livingston Survey has a relatively low frequency (semi-annual), while in the case of the ASA-NBER Survey, the number of responses is not stable over time and the inception date is very late (1981).[5] Furthermore, in both cases the latent variable about which investors are uncertain is not the regime of monetary policy, but inflation itself.

A direct quantification of the stance of monetary policy is provided by the Boschen-Mills (1995) and the Bernanke-Mihov (1998) indexes of monetary policy stance. These indexes have been constructed using standard monetary variables and provide the best identification of the monetary policy regime. Unfortunately, they are constructed with data not immediately available to the market. Moreover, they do not provide a way of quantifying the degree of uncertainty around them. We therefore need to construct a measure that allows us to quantify both the market expectations about the regime of monetary policy and the market uncertainty around such expectation.

We therefore go for the direct approach. We first estimate investors' beliefs on the type of monetary regime and their volatility and then we construct the index of monetary policy uncertainty. We assume that policy changes represent a latent stochastic process which can be estimated jointly with the parameters of the model. This properly accounts for the instability of the regimes, avoids arbitrary assumptions and provides a direct measure of the regimes *as they are perceived by the market.* We will proceed in two steps: first we estimate and identify the regimes of monetary policy and then we construct a measure of monetary policy uncertainty.

5.1 Monetary policy regimes

To identify the regimes of monetary policy we use a Markov switching VAR, with regime shifts following a two-state Markov chain. The VAR includes five variables: the excess return on the market portfolio, the corresponding dividend yield, the risk-free

[5] See in particular, Dean Croushore, Introducing: the Survey of Professional Forecasters, Business Review, Nov/Dec 1993.

real rate, the consumer price inflation index (CPI) and the growth rate of real GDP. The non-financial data is provided by the Federal Reserve. The model is estimated by maximum likelihood (ML), using quarterly data covering the period 1965:3-1998:4. An EM algorithm is used to estimate the vector of parameters and the hidden Markov process. An explanation of it is provided in the Appendix.

The regimes are defined in terms of their probabilities (πs) and described in Figure 3. The first regime corresponds to a restrictive policy stance. To identify the regimes we look at their correlations with the standard indexes of monetary policy. The correlation is very high, between 38.3% for the Boschen-Mills index and 48.1% for Bernanke-Mihov measure. This provides a strong evidence for the quality of our identification. As a further evidence, we consider the correlation with the Romer and Romer (1989) index of monetary policy, constructed with the official documents ("minutes") of the FOMC meetings. For the common period, the four periods of restrictive police stance (December 1968, April 1974, August 1978 and October 1979) identified by our measure of monetary policy stance coincide with the ones identified by the Romer and Romer index. This strongly supports our identification as the unconditional probability of the first regime is just 0.31 and the likelihood that this result is due do chance is well below 1%.

It is however possible that such correlations are actually due to spurious effects: this could happen, for instance, if the Markov process we estimate simply captures cyclical movements in the economic environment. To address this issue, we regress our monetary regimes on alternative measures of monetary policy stance and on a proxy for business cycle fluctuations. We estimate the model:

$$\pi_{b,t} = \alpha + \boldsymbol{\beta} M_t + \gamma BC_t + \varepsilon_t, \tag{20}$$

where $\pi_{b,t}$ represents our probability of non-accommodative monetary policy regime as derived from the Markov-switching VAR and M_t and BC_t are, respectively, the index of monetary policy stance (either the Bernanke-Mihov or the Boschen-Mills one) and a proxy for business cycle fluctuations. We estimate alternative specifications with different indexes.[6] In particular, we consider four measures derived from the NBER Business Cycle Reference Dates (two indicator variables, one for Peaks and the other for Troughs; the difference between the previous two variables; a proxy for business cycle fluctuations obtained by joining NBER turning points with linear segments), as well as James Stock's Coincident, Leading and Recession Indexes and some transformations of them (a detailed description is reported in the Appendix). If the correlation between our measure of the stance of monetary policy and the exogenous ones were due to

[6]We thank J Eberly and R. Jaganathan for suggesting these indexes to us.

spurious correlation, we would expect it to disappear once we control for business cycles.

In Table 1 we report the results for the case when the Bernanke-Mihov index of stance of monetary policy is used.[7] The results are quite clear-cut: the *t-statistic* on the β coefficient is strongly significant and with the expected sign in all the specifications considered. Furthermore, the statistics for γ is in general less significant that the corresponding statistics for β. This suggests that our measure of perceived regimes of monetary policy is indeed mostly related to monetary policy. [8]

Finally, a direct inspection of the index (Figure 3) suggests a correct identification of the regimes. The second regime (accommodative monetary policy) is more prevalent in the periods from 1965 to the 70s, with the exception of the sub-period 1966-1967. This is consistent with standard explanation that "money growth accelerated ... and persisted through the 1970s. US inflation began to accelerate in 1964, with a pause in 1966-1967, and was not curbed until 1980" (Bordo and Schwartz, 1999). It is only in the second part of the 70s that monetary policy gradually becomes tighter with a change in the operating procedures.[9] Tightening can be clearly identified during the Voker era. The second regime seems to prevail again in the end of the sample, when stable and low inflation allows the Fed to follow a less tight policy and to accommodate the "irrational exuberance" of the stock market.

5.2 A market-based measure of monetary policy uncertainty

Once we found the perceived regimes of monetary policy (i.e., π_a), we can construct a measure of policy uncertainty. In particular, we use the index $I_t = \pi_{a,t}(1 - \pi_{a,t})$, where $\pi_{a,t}$, is the probability investors attach to monetary policy being accommodative, as estimated from the Markov-switching VAR model. A visual description of the behavior of this index is provided in Figure 3. It is interesting to note the correlation between perceived monetary policy regimes, measured by $\pi_{a,t}$, and investors' uncertainty, prox-

[7] The analysis based on the Boschen-Mill Index provides analogous results and they are available upon request from the authors. Hoewever, these results are less reliable than the ones based on the Bernanke-Mihov Index as the Boschen-Mill Index is a discrete variable with limited range of variation.

[8] The residual correlation with the indicators of business cycle are due to the inherent link between monetary policy and business cycle.

[9] In the early 1970s, the FED gradually abandoned indirect targeting in favor of direct targeting of the Federal funds rate, allowing movements only within a narrow band (usually 25 basis point), specified by the FOMC each time it met. In 1975, the FED started to adopt and announce one-year money growth targets, in application of the Congressional Resolution 133. In 1979, targeting of non-borrowed reserves in place of direct Federal funds rate targeting was adopted. Finally, in October 1982 the FOMC decided to abandon non-borrowed reserves targeting in favor of managing borrowed reserves.

ied by I_t. In general, high uncertainty seems to be related to expansionary regimes, while contractionary regimes are more stables. Higher volatility and lower persistence are more common in regimes of expansionary monetary policy.

The next step is to construct a tracking portfolio that mimics our index of policy uncertainty (I_t). We follow this approach as the tracking portfolio provides a direct measure of the possibility for investors to hedge the risk due to monetary policy uncertainty. The construction of such a portfolio allows us to see whether this particular source of uncertainty is actually hedgeable (Campbell, Lo and MacKinlay, 1997, Cochrane, 2000) and if this hedgeability changes over time. However, it is worth stressing that *the results do not depend upon it.* Indeed, we replicated the tests of the main specifications using the index of policy uncertainty, without the construction of the tracking portfolio. The results (not reported) are consistent with the ones reported.[10]

We rely on the technique developed by Lamont (2000) and Vassallou (2001). The intuition underlying this methodology is that innovations in returns, by reflecting information about future cash flows and discount rates, depend on changes in expectations about the prospective value of variables affecting cash flows. Provided that market expectations are properly accounted for, portfolios whose innovations have a high correlation with revisions in expectations about fundamentals can be used to explain the cross-sections of asset returns.

We therefore regress I_t, viewed as a measure of information uncertainty, on a set of portfolios, the so-called base assets, and on instrumental variables, which summarize the information available to market participants and proxy for market expectations. The regression model is:

$$I_{t+k} = \alpha + \boldsymbol{\theta}\mathbf{B}_t + \boldsymbol{\zeta}\mathbf{Z}_{t-1} + \varepsilon_{t+k}, \tag{21}$$

where $\mathbf{B}_t$ represents the set of base assets,[11] $\mathbf{Z}_t$ is the set of instruments and I_{t+k} is the realized future value of uncertainty.[12] Given that the tracking portfolios are

[10]They are available upon request.

[11]The base assets are *term*, *junk* and *ME1/ME5*. *Term* stands for the spread between the yield on 10-year Treasury bonds and 3-month Treasury bills; *junk* is the difference between Moody's Baa and Aaa corporate yields; *ME1/ME5* is the return on an arbitrage portfolio which is long on stocks of small firms (first NYSE market equity quintile) and short on stocks of big firms (fifth NYSE market equity quintile). Their returns are in excess of the riskless rate.

The instrumental variables are expected inflation, actual inflation, inflation measured by changes in the producer price index, the excess return on the market portfolio and the share of durables consumption over total consumption.

[12]The selected tracking portfolios are chosen so as to maximize the fitting of equation (21). In order to assess whether the results described in the paper are robust, a few other tracking portfolios, which combine portfolios constructed on the basis of book-to-market categorization and portfolios constructed on the basis of industrial categorization (2-digit SIC codes), have been estimated and

generated regressors, we also compute the White-corrected t-statistics. Table 2 reports the results of the estimation of equation (21). It is worth noticing that even if the R^2 is lower than the ones found by Lamont and Vassallou, it is still comfortably high, especially considering that the factors we are trying to mimic are not so persistent or easily forecastable.

The tracking portfolio $\boldsymbol{\theta}\mathbf{B}_t$ is our measure of monetary policy uncertainty Φ_t. To define a measure of fundamental uncertainty we rely on recent studies (Liew and Vassallou, 2001 and Vassallou, 2000) that show that the FF factors are good proxies of news on future GDP growth and are correlated with innovations on other macroeconomic fundamentals. We therefore consider both a CAPM one factor specification and a specification based on the three FF factors. In the former case we use as a proxy of fundamental uncertainty the excess return on the market portfolio, while in the latter case we use the three FF factors (i.e., *Market*, *SMB* and *HML* [13]).

6 Evidence on the market price of policy uncertainty

We will proceed as follow. First, we will estimate whether the Fisher puzzle is a feature of our data (restriction 18). Then, we will focus on the pricing relationship 5 and assess whether monetary uncertainty affects stock returns and is priced. Finally, relying on this pricing relationship, we will go back to the Fisher puzzle, compare restrictions 17 and 19 and see whether, by properly conditioning on the uncertainty factors, the puzzle disappears.

6.1 Inflation and stock returns: the Fisher puzzle

We start by seeing whether in our sample the Fisher puzzle exists. We use data from July 1965 to December 1998. We will mostly use the 25 book-to-market portfolios and 17 industry portfolios. Descriptive statistics of them are provided in Table 3, Panel A

used as an alternative. No notable differences with respect to the evidence shown in the paper, apart from worse fitting of the regression model (21),were found. Such results are available upon request from the authors.

[13] *Market* is the excess return of the market aggregate portfolio over the riskless rate, book-to-market (*HML*) is the difference between the average returns on the two portfolios with high book-to-market ratios and the average returns on the two portfolios with low book-to-market ratios. Size (*SMB*) is the difference between the average returns on three small stock portfolios and the average returns on the three big stock portfolios.

and B. To test for the existence of the Fisher puzzle, we estimate restriction 18:

$$R_{i,t} = \alpha + \beta_i Infl_t^e + \varepsilon_{i,t}, \tag{22}$$

where $Infl_t^e$ is inflation expected on the basis of information up to time t and $R_{i,t}$ represents the excess returns of the *i-th* portfolio. Expected inflation is constructed by using he one-period-ahead forecast based on the Markov-switching VAR specification allowing for regime-shifts. That is, $Infl_t^e = \pi_{a,t} Infl_{a,t}^e + \pi_{b,t} Infl_{b,t}^e$, where $\pi_{a,t}$ and $\pi_{b,t} = 1 - \pi_{a,t}$ are the probabilities (conditional upon information as of time $t-1$) of the two monetary policy regimes and $Infl_{a,t}^e$ and $Infl_{b,t}^e$ are expectations as of time $t-1$ of time-t inflation in the first and second regime respectively. In order to check the consistency between our measure of expected inflation and the one based on extra-sample evidence, we compare it with the University of Michigan Inflation Expectations. The correlation between the two measures is 0.93.

Table 4, Panel A and B, reports the results for the book-to-market and size portfolios and for the industry portfolios respectively. In all cases and for all portfolios a highly significant negative correlation between expected inflation and excess returns is found, confirming that a "Fisher puzzle" exists, without regard of the sample period or the criterion used in forming portfolios.

These findings show that expected inflation affects risk premia and that in our sample the relationship is negative as found in the literature. We now proceed to explain why, by focusing on restrictions on how policy uncertainty affects the relationship between expected inflation and excess returns.

6.2 Evidence of Pricing

We proceed to directly testing whether monetary policy uncertainty is priced. We test the restrictions of equation 16. The additional factor (Φ_t) is constructed as the tracking portfolio that mimics monetary policy uncertainty as was defined in the previous section. In the unrestricted case, the vector of factors is $\widetilde{\mathbf{F}}_t = [\mathbf{F}_t, \Phi_t]'$. Data on the FF factors is derived from Kenneth French's website. The information variables are the ones used in the literature (Ferson and Harvey, 1991,1993 and 1999, Dumas and Solnik, 1995) and comprise: a constant, a January dummy, one month T-Bill yield (*T-bill*), the dividend yield of the S&P 500 index (*div*), the term premium, i.e. the spread between a 10-year and 1-year Treasury bond yield, (*term*), the junk premium, i.e. the spread between Moody's Baa and Aaa corporate bond yields (*junk*), the spread between the one month lagged returns of a three month T-bill and the difference between the one month returns of a three month and one month T-bill (*hb3*).

The tests are based on the GMM estimation of the of Fx*(1+m)* conditions of equation 16 We consider both industry portfolios and size and book-to-market portfolios.

While these factors are expected to proxy for fundamental uncertainty, they may also be related to monetary policy. If this were the case we would expect them to indirectly capture part of the monetary policy uncertainty we are looking for. Therefore, in order to appraise more precisely the role of uncertainty about monetary policy, we also estimate two alternative specifications: one where the factor that proxies for policy uncertainty (Φ_t) has been orthogonalized with respect to the FF factors (Panels C and D) and one specification where the FF factors have been orthogonalized with respect to Φ_t (Panels E and F) [14] This allows us to separate the component of uncertainty which is due to monetary policy uncertainty from the components which depend on fundamentals. If the FF factors already incorporate part of the monetary policy uncertainty, this last specification allows us to remove from the standard FF factors the part of them that is related to monetary policy uncertainty.

We report the values of the estimated coefficients ($\phi_f s$) in Table 5, Panels A, C and E, for the size portfolios and Panels B, D and F for the industry portfolios. The last row of each panel reports the χ^2 of the model and the associated *p-value.* The results show that we cannot reject the null at any confidence level, both for the case of size and book-to-market portfolios and industry portfolios. Indeed, for both cases the *p-value* is equal to 0.99. This provides a first evidence of the quality of the model and the fact that monetary policy uncertainty is priced.

Furthermore, the analysis of the coefficients contained in $\boldsymbol{\phi}_{\Phi_t}$ shows that most of them are highly significant. In particular, the price of risk of monetary policy uncertainty is related to *div*, *junk, term, hb3,* the January Dummy and the constant in the case of the bok-to-market and size portfolios and to *div*, *junk, term,* the January Dummy and the constant in the case of the bok-to-market and size portfolios. The $\boldsymbol{\phi}_{\Phi_t}$ are statistically significant at any significance level. These results suggest that monetary policy uncertainty is significant, is priced and provides explanatory power for stock returns.

6.3 Inflation and stock returns: the Fisher relationship revived

We can now verify how uncertainty about monetary policy regimes affects the relationship between stock returns and inflation. In particular, we want to see whether the joint use of fundamental uncertainty (F_t) and monetary policy uncertainty (Φ_t) as spelled out in equation 5 can explain the Fisher puzzle (restriction 19). We therefore

[14] The orthogonalization of the three risk factor is obtained by taking the residuals of the regression of each of them on the tracking portfolio for I_t.

estimate:

$$R_{i,t} = \alpha + \boldsymbol{\delta}_i'\mathbf{F}_t + \gamma_i\Phi_t + \beta_i Infl_t^e + \varepsilon_{i,t}, \tag{23}$$

where $\mathbf{F}_t$ is the vector of returns on factors that proxy for fundamentals. Restrictions (17) and (19) require that $\gamma_i > 0$ and $\beta_i = 0$. That is, if information uncertainty is priced, we expect the relationship between expected inflation and returns to be non-negative. Indeed, the more investors are uncertain about future monetary policy actions, the higher risk premia should be.

Table 6, Panel A and B, reports the results for the three-factor specification [15] for the book-to-market and size portfolios and for the industry portfolios respectively. The results strongly support our working hypothesis. Regarding restriction (18), the coefficient on monetary policy uncertainty is positive and strongly significant, both in the case of book-to-market and size portfolios and in the case of industry portfolios (i.e., $\gamma_i > 0$). The estimated coefficient remains highly significant even after the application of the White correction to control for the problem of generated regressors. In particular, the tracking portfolios are positive and strongly significant in 24 out of 25 cases for the size and book-to-market portfolios and in 13 out of 17 cases for the industry portfolios.

It is interesting to note that the impact of policy uncertainty seems to be negatively related to the size of the company: the bigger the company the lower the impact. This effect is approximately monotonic, both in the value of the coefficients and in their level of significance. The value of γ increases from a minimum of -0.06 for the biggest companies to a maximum of 0.82 for the smallest ones and the respective *t-statistics* rise from -1.09 to 21.30. This seems to suggest that the biggest companies are better able to hedge uncertainty, either because they operate in many sectors (industrial diversification) or because they are better able to financially hedge themselves (financial diversification).

In the case of industry portfolios, the portfolios that do not seem to be affected by monetary policy uncertainty are mostly the ones formed of stocks that belong to sectors such as Utilities, Oil, Consumer Products and Financial Services. In the case of Utilities and Oil this suggests that these sectors have a sort of "built in hedge" against monetary policy shocks. Indeed, the cases when monetary policy is tighter are presumably the ones with higher inflations. These should be the very cases in which oil- and energy-related stocks should fare better. In the case of financial services, instead, the lack of correlation between monetary uncertainty and the financial sector confirms the ambiguous relationship between it and inflation already studied in the literature. Indeed, while it seems proved that the industrial sector is negatively affected by a tightening of the monetary policy, the results for the financial sector are less clear-cut

[15] The results for the one-factor specification agree and are available upon request from the authors.

and it may even be argued that the returns of the financial companies are positively affected by tight monetary policy.[16]

In order to assess the robustness of the results to the way portfolios are constructed and in line with the findings of Brennan, Chordia and Subrahmanyam (1998), we also estimate equation (23) by grouping portfolios according to three alternative criteria, namely (i) the ratio between cash flow and market price, (ii) the price-earning ratio and (iii) the dividend yield. The results, reported in Table 6, Panel C, agree with the previous ones. In particular, monetary policy uncertainty is strongly positively related to stock returns in 8 out of 10 portfolios in the cases of both cash flow-to-price portfolios and earnings-to-price portfolios and in 9 out of 10 portfolios in the case of dividend-yield portfolios.

Also restriction (19) seems to be supported by the data as in most instances β_i is not statistically different from zero. In particular, expected inflation is significant only in 6 out 25 cases for the size and book-to-market portfolios and in 4 out of 17 cases for the industry portfolios. Furthermore, for both cash flow-to-price portfolios and earnings-to-price portfolios, expected inflation is non significant in 9 out of 10 portfolios, while it is never significant in the case of dividend-yield portfolios. This supports the main theoretical findings.

As additional robustness check, we also investigated the relative importance of fundamental uncertainty and monetary policy uncertainty, by re-estimating equation 23 without the proxy for monetary policy uncertainty. The results (not reported) show that the goodness-of-fit of the model, as measured by the *Adjusted* R^2, sharply deteriorates, which suggests that a significant fraction of the explanatory power of model (23) is captured by the tracking portfolio. When Φ_t is not included in the regression, the average *Adjusted* R^2 falls from 0.9 to 0.8 on average. Moreover, the coefficient on expected inflation becomes again statistically significant.[17] This suggests that fundamental uncertainty by itself is not enough to solve the Fisher puzzle, and

[16] In general, the literature has identified different channels through which inflation and an accommodative monetary policy negatively affect banks' cash flows. In particular, Kessel (1956) and Alchian and Kessel (1960) argue that banks' shareholders would suffer from inflation because banks are net holders of financial assets whose contractual characteristics are fixed in nominal terms. More recently Dermine (1985 and 1987) considers the tax burden. He argues that, being taxes calculated on nominal profits, "the increase in after-tax earnings fueled by inflation is not sufficient to finance a constant level of real dividends and the retained earnings that are required to satisfy an exogenous capital adequacy ratio". Therefore, the existence of exogenously imposed capital adequacy ratios together with the fact that taxes are calculated on nominal returns would make inflation negatively affect banks cash flows. Empirical evidence seems to confirm this hypothesis (Dermine, 1999).

[17] The sign of the coefficient is now positive. This contrasts with the strict definition of the Fisher relationship which would impose a zero correlation between excess returns and expected inflation (restriction 19)

that it is the joint presence of both fundamental and policy uncertainty that is required as indicated by the model.

7 Conclusion

We have studied the relationship between inflation and stock returns from a new perspective. We have argued that inflation is also a signal used by the investors to infer the stance of monetary policy. Investors do not know the stance but learn it. The learning process generates uncertainty that increases the risk premium. Depending on investors' beliefs on the stance of monetary policy, a change in consumption prices has different effects on the risk premium. We showed that a change in consumption prices that confirms investors beliefs leads to a reduction in risk premium, while a change that contradicts them increases risk premia.

We showed how this helps to explain the Fisher puzzle by both realistically calibrating our model with US data and estimating directly the empirical restrictions of the model. In particular, we constructed a market-based proxy of monetary policy uncertainty and we showed that it is priced. Moreover, we showed that, by conditioning on it, the Fisher puzzle disappears.

Our results provide a link between asset pricing and monetary economics. They suggest a new channel through which the Fed affects the financial markets that has not been properly explored up to now. Moreover, they shed new light on the debate about "rules versus discretion", quantifying the cost - in terms of higher risk premium - of the lack of full disclosure or discretional behavior of the Fed. It would be interesting to extend our analysis to the international dimension to see whether countries characterized by different degrees of disclosure of the central bank's operating procedures and targets would also display different impacts of monetary policy uncertainty on prices.

8 Appendix

Proof of Theorem 1

We first solve investor's learning problem and then we define the equilibrium stock price. Investors observe D_t, C_t and p_t (signals) and try to infer the value of θ_t.[18] The unobservable component (θ_t) can take values a and b (that is $E = [a, b]$). From Liptser and Shiryayev (pag. 333) we know that the posterior probability of a is:

$$d\pi_{a,t} = (1 - 2\pi_{a,t})\lambda dt + \pi_{a,t}(\boldsymbol{\mu}_{i,t} - \overline{\boldsymbol{\mu}_t})'(\boldsymbol{\Sigma}\boldsymbol{\Sigma}')^{-\frac{1}{2}} d\mathbf{v}_t \tag{24}$$

[18] Investors observe nominal Dividends (D_t^n). However, given that they also observe consumption prices (p_t), the informational content of the dividends coincides with their real component (D_t).

where $\boldsymbol{\mu}_i = (\mu_D + \beta\theta_t,\ \mu_p + \delta\theta_t,\ \mu_c)$', $\overline{\boldsymbol{\mu}_t} = \sum_{j\in\{a,b\}} \boldsymbol{\mu}_{j,t}\pi_{j,t}$, $\boldsymbol{\Sigma} = (\mathbf{b}_D,\ \mathbf{b}_p,\ \mathbf{b}_c)'$ and $\mathbf{b}_D = (\sigma_D, 0, 0)'$, $\mathbf{b}_p = (0, \sigma_p, 0)'$ and $\mathbf{b}_c = (\sigma_{c_D}, 0, \sigma_e)'$. The vector $\boldsymbol{\nu} = (\nu_D,\ \nu_p,\ \nu_e)$, defined on the agents' new filtration, follows:

$$d\mathbf{v}_t{=}(\boldsymbol{\Sigma}\boldsymbol{\Sigma}')^{-\frac{1}{2}}(d\mathbf{W}_t - \overline{\boldsymbol{\mu}_t}dt). \tag{25}$$

We can also rewrite equation 24 as:

$$\begin{aligned} d\pi_{a,t} &= (1-2\pi_{a,t})\lambda dt + \pi_{a,t}(1-\pi_{a,t})(a-b)\left(\beta\Omega_t d\nu_{D,t} + \delta d\nu_{p,t} - \gamma d\nu_{e,t}\right) = \\ &= \mu_{\pi_a,t}dt + \boldsymbol{\sigma}_{\nu,t} d\boldsymbol{\nu}_t, \end{aligned} \tag{26}$$

where: $\mu_{\pi_a,t} = (1-2\pi_{a,t})\lambda$, $\Omega_t = \frac{\sigma_{c_D} - \sigma_e}{\sigma_e}$, $\boldsymbol{\sigma}_{\nu,t} = (\sigma_{\nu_D,t},\ \sigma_{\nu_p,t},\ \sigma_{\nu_e,t})'$, where $\sigma_{\nu_D,t} = \pi_{a,t}(1-\pi_{a,t})(a-b)\beta\Omega_t$, $\sigma_{\nu_D,t} = \pi_{a,t}(1-\pi_{a,t})(a-b)\delta$ and $\sigma_{\nu_e,t} = -\pi_{a,t}(1-\pi_{a,t})(a-b)\gamma$.

We can now define the equilibrium stock price. The price of the stock is the present discounted value of its future dividends, discounted by the stochastic discount factor (Campbell and Kyle, 1993, Wang, 1993), that is:

$$S_t^n = E_t\left[\int_t^\infty \frac{n_s D_s^n ds}{n_t}\right]. \tag{27}$$

where S_t^n is the nominal value of the stock, D_t^n is the nominal dividend and n_t is the nominal stochastic discount factor. We define $S(s)$ as the real price of the stock and r^n the nominal interest rate. Given the law of motion of the real consumption process described in equation 4, in equilibrium the *real* pricing kernel is: $m_t = u_c(t, C_t) = e^{-\phi t}C^{-\rho}$. This implies that the the law of motion of the real stochastic discount factor is:

$$dm_t = k_t m_t dt - \rho m_t \sigma_D dz_{D,t}, \tag{28}$$

where $k_t = -\phi - \rho(\mu_c + \gamma\theta_t) + \frac{1}{2}\rho(\rho+1)\mathbf{b}_c\mathbf{b}_c'$.

Given that the nominal stochastic discount factor (n_t) is a function of both real stochastic factor (m_t) and the price level (p_t), it can be defined as: $n_t = \frac{m_t}{p_t}$. The nominal dividend can be therefore expressed in terms of the real dividend (D_t) and of the price level (p_t) as: $D_t^n = D_t p_t$. Its law of motion follows:

$$\begin{aligned} dD_t^n &= p_t dD_t + D_t dp_t = D_t^n\left[\mu_D + \beta\theta_t + \mu_p + \delta\theta_t\right]dt + D_t^n\left[\sigma_D dz_{D,t} + \sigma_p dz_{p,t}\right] = \\ &= D_t^n \mu_{D^n} dt + D_t^n\left[\sigma_D dz_{D,t} + \sigma_p dz_{p,t}\right]. \end{aligned} \tag{29}$$

To determine the price of the stock we use Proposition 1 from Veronesi (1999) which relates the value of a stock to the present discounted value of future dividends. For the general case where the underlying regimes ($\theta_{i,t}$) can take $i = 1...N$ values, the nominal price of the stock (S_t^n) can be defined as a function of nominal dividends and nominal discount factors, such as:

$$S_t^n n_t \;=\; E_t\left[\int_t^\infty n_s D_s^n ds\right] = D_t^n E_t\left[\int_t^\infty \frac{n_s D_s^n}{n_t D_t^n} ds\right] =$$

$$
\begin{aligned}
&= D_t^n E_t\left[\int_t^\infty \frac{m_s D_s}{m_t D_t} ds\right] = D_t^n \sum_{i=1}^N E_t\left[\int_t^\infty \frac{\Xi_s}{\Xi_t} ds|\theta_t = \theta_{i,t}\right]\pi_{i,t} = \\
&= D_t^n \sum_{i=1}^N C_{i,t}\pi_{i,t}, \qquad (30)
\end{aligned}
$$

where $\Xi_t = m_t D_t$ and $C_{i,t} = E_t\left[\int_t^\infty \frac{\Xi_s}{\Xi_t} ds|\theta_t = \theta_{i,t}\right]$. Ξ_t follows:

$$
d\Xi_t = [k + \mu_D + \beta\theta_t - \rho\sigma_D^2]dt + [1-\rho]\sigma_D dz_{D,t} = \mu_{\Xi,t}dt + [1-\rho]\sigma_D dz_{D,t}, \qquad (31)
$$

The solution requires us to determine the value of $C_{i,t}$. Let's define $\mathbf{A}_t = -\mathbf{\Lambda} - diag(\mu_{\Xi_t})$. Given that we consider only two regimes, (θ_t can only take values a and b), we have that:

$$
\mathbf{A} = -\begin{bmatrix} -\lambda & \lambda \\ \lambda & -\lambda \end{bmatrix} + \begin{bmatrix} -\mu_{\Xi_t|\theta_t=a} & 0 \\ 0 & -\mu_{\Xi_t|\theta_t=b} \end{bmatrix} = \begin{bmatrix} -\mu_{\Xi_t|\theta_t=b} + \lambda & -\lambda \\ -\lambda & -\mu_{\Xi_t|\theta_t=a} + \lambda \end{bmatrix}. \quad (32)
$$

$C_{i,t}$ can be computed using the relationship $\mathbf{C}_t = \mathbf{A}_t^{-1}\mathbf{1}_m$, where $\mathbf{1}_m$ is a unity vector. That is, we have that: $C_{a,t} = \frac{2\lambda - \mu_{\Xi_t|\theta_t=b}}{(-\mu_{\Xi_t|\theta_t=a}+\lambda)(-\mu_{\Xi_t|\theta_t=b}+\lambda)-\lambda^2}$ and $C_{b,t} = \frac{2\lambda - \mu_{\Xi_t|\theta_t=a}}{(-\mu_{\Xi_t|\theta_t=a}+\lambda)(-\mu_{\Xi_t|\theta_t=b}+\lambda)-\lambda^2}$. The nominal price is:

$$
S_t^n = D_t^n \sum_{i\in\{a,b\}} \pi_{i,t} C_{i,t}. \qquad (33)
$$

The law of motion of the nominal price of the asset is determined by totally differentiating equation 33. That is:

$$
\begin{aligned}
\frac{dS_t^n}{S_t^n} &= \left[\mu_{D_t^n,t}dt + D_t^n\left[\sigma_D dz_{D,t} + \sigma_p dz_{p,t}\right]\right] + \frac{\sum_{i\in\{a,b\}} C_{i,t}\left\{\mu_{\pi,t}dt + \boldsymbol{\sigma}_{\nu,t}d\boldsymbol{\nu}_t\right\}}{\sum_{i\in\{a,b\}} C_{i,t}\pi_{i,t}} + \\
&\frac{\sum_{i\in\{a,b\}} C_{i,t}\pi_{i,t}\left\{D_t^n\boldsymbol{\sigma}_{\nu,t}d\boldsymbol{\nu}_t(\boldsymbol{\sigma}_{D,t}dz_{D,t} + \boldsymbol{\sigma}_{p,t}dz_{p,t})\right\}}{\sum_{i\in\{a,b\}} C_{i,t}\pi_{i,t}}. \qquad (34)
\end{aligned}
$$

Let's specify that $a = 1$ and $b = -1$. Using equation 25, we have that: $dz_{D,t} = \frac{1}{\sigma_D}\{d\nu_{D,t} - \beta\left[\theta_t + (1 - 2\pi_{a,t})\right]dt\}$ and $dz_{p,t} = \frac{1}{\sigma_p}\{d\nu_{p,t} - \delta\left[\theta_t + (1 - 2\pi_{a,t})\right]dt\}$. After substituting out for $C_{a,t}$ and $C_{b,t}$, we can write:

$$
\begin{aligned}
\frac{dS_t^n}{S_t^n} &= \{\mu_D + \mu_p - (1-2\pi_{a,t})(\beta+\delta) + (1-2\pi_{a,t})\frac{2(\beta-\rho\gamma)\lambda}{\Psi_t} + \\
&\pi_{a,t}(1-\pi_{a,t})\frac{4(\beta-\rho\gamma)}{\Psi_t}(\beta\Omega_t + \delta - \gamma)\}dt + \boldsymbol{\sigma}_{s,t}d\boldsymbol{\nu}_t, \qquad (35)
\end{aligned}
$$

where $\Psi_t = \sum_{i\in\{a,b\}} C_{i,t}\pi_{i,t} = C_{a,t}\pi_{a,t} + C_{b,t}\pi_{b,t} = -\mu_D - k + 2\lambda + (2\pi_{a,t}-1)(\beta-\gamma\rho) + \rho\mathbf{b}_D\mathbf{b}_D'$, $\Omega_t = \frac{\sigma_{c_D}-\sigma_e}{\sigma_e}$, $\boldsymbol{\sigma}_{s,t} = (1+\frac{(\mu_{\Xi_t|\theta_t=a}-\mu_{\Xi_t|\theta_t=b})}{\Psi_t}\sigma_{\nu_{D,t}}, 1+\frac{(\mu_{\Xi_t|\theta_t=a}-\mu_{\Xi_t|\theta_t=b})}{\Psi_t}\sigma_{\nu_{p,t}}, \frac{(\mu_{\Xi_t|\theta_t=a}-\mu_{\Xi_t|\theta_t=b})}{\Psi_t}\sigma_{\nu_{e,t}})$ and $k = -\phi - \rho\mu_c + \frac{1}{2}\rho(\rho+1)b_c b_c'$. Therefore, we can define the expected value of the nominal stock return as:

$$
E_t(\frac{dS_t^n}{S_t^n})/dt = \mu_{D,t} + \mu_{p,t} - (1-2\pi_{a,t})(\beta+\delta) + (1-2\pi_{a,t})\frac{2(\beta-\rho\gamma)\lambda}{\Psi_t} + \Phi_t, \qquad (36)
$$

where $\Phi_t = \pi_{a,t}(1-\pi_{a,t})\frac{4(\beta-\rho\gamma)}{\Psi,t}(\beta\Omega_t+\delta-\gamma)$. We can also derive the equilibrium riskless real rate of return, as:

$$E\left[r_t\right] = \phi + \rho\mu_c - \frac{1}{2}\rho(\rho+1)\mathbf{b}_c\mathbf{b}_c' + \rho\gamma\theta_t, \tag{37}$$

and expected inflation as:

$$E\left[\frac{dp_t}{p_t}\right]/dt = \left[\mu_p + (2\pi_{a,t}-1)\delta\right]. \tag{38}$$

The expected nominal riskless rate is:

$$\begin{aligned} E[r_t^n] &= E[r_t] + \mu_p + \delta(2\pi_{a,t}-1) = \\ &= \phi + \rho\mu_c - \frac{1}{2}\rho(\rho+1)\mathbf{b}_c\mathbf{b}_c' + \mu_p + (2\pi_{a,t}-1)(\delta+\gamma\rho). \end{aligned} \tag{39}$$

Using equation 39 and 36, we find that the expected excess rate of return on the stock (risk premium) is:

$$\begin{aligned} E\left[R_t\right] &= E[\frac{dS_t^n}{S_t^n} + \frac{D_t^n}{S_t^n} - r_t^n dt]/dt = \\ &= \mu_{D,t} + \mu_{p,t} - (1-2\pi_{a,t})(\beta+\delta) + (1-2\pi_{a,t})\frac{2(\beta-\rho\gamma)\lambda}{\Psi_t} + \\ &\quad \frac{D_t^n}{S_t^n} - \phi - \rho\mu_c + \frac{1}{2}\rho(\rho+1)\mathbf{b}_c\mathbf{b}_c' - \mu_p - (2\pi_{a,t}-1)(\delta+\gamma\rho) + \Phi_t \\ &= F_t + \Phi_t. \end{aligned} \tag{40}$$

Calibration of the model

The model is calibrated to real data. Given that the unit period is a quarter, all the parameters are defined on a quarterly basis. Using the data provided by the Federal Reserve Bank of St. Louis (”FRED”) for the period January 1965-December 1998, we find that, at a *quarterly* frequency, $\mu_p = 0.0112$ and $\sigma_p = 0.0062$. Also, we estimate for the analogous period $\mu_{D^n} = 0.0220$, $\sigma_{D^n} = 0.0222$, $\mu_D = 0.0108$ and $\sigma_D = 0.023$. The values of the parameters for real consumption are $\mu_c = 0.0077$ and $\sigma_c = 0.009$. The decomposition of the volatility of consumption is done by assuming that dividends represent roughly 5% of overall consumption as reported in the literature (see also Berk, Green and Naik, 1999, Cecchetti, Lam and Mark, 1993, Campbell and Cochrane, 1999, Barberis, Huang and Santos, 2001). This implies that $\sigma_e = \sqrt{\sigma_c^2 - 0.05^2\sigma_{c_D}^2/0.95^2}$, where $\sigma_{c_D} = \sigma_D$.

Accordingly, we assume that the impact of monetary policy on consumption prices and real dividends is assumed to be equal to 5% of that on dividends ($\gamma = 0.05\ \beta$). The impact of monetary policy on prices is assumed to be equal to 2%, that is to an yearly impact corresponding to a 2% inflation. It also corresponds to the yearly value of price volatility across the period. We consider different values of β in the interval [0.001-0.5]. The case of $\beta = 0.5$ corresponds to the case of an impact of monetary policy on consumption (and GDP) equal to 2.5%.

In order to determine the value of λ we consider the transitional probability $P_t(a, b)$, that is the probability of moving from one regime to another. Using quarterly data the Markov-switching model delivers an estimate of $P_t(a, b) = 0.1640$. The degree of risk aversion (ρ) is assumed to be equal to 2. However, the results are robust to a change in ρ.

In order to determine λ we apply Karlin and Taylor (pag. 151-152). Given $\mathbf{\Lambda}$ as defined above, we have that:

$$P_s = \frac{1}{2\lambda} \begin{pmatrix} \lambda(1 + e^{-2\lambda s}) & \lambda(1 - e^{-2\lambda s}) \\ \lambda(1 - e^{-2\lambda s}) & \lambda(1 + e^{-2\lambda s}) \end{pmatrix}. \tag{41}$$

We can, therefore, define λ, by solving: $0.5(1 - e^{-2\lambda s}) = 0.1640$,where $s = 1$ for a unit period equal to a quarter. The solution provides $\lambda = 0.1987$.

The data.

The data and the way of constructing the portfolios comes from K. French's web page. The industry portfolios are constructed by first assigning each NYSE, AMEX, and NASDAQ stock to an industry portfolio at the end of June of year t based on its four-digit SIC code at that time and then computing the returns from July of t to June of $t + 1$. The size and book-to-market portfolios are constructed at the end of each June as the intersections of 5 portfolios formed on size (market equity, ME) and 5 portfolios formed on the ratio of book equity to market equity (BE/ME). The size breakpoints for year t are the NYSE market equity quintiles at the end of June of t. BE/ME for June of year t is the book equity for the last fiscal year end in t-1 divided by ME for December of t-1. The BE/ME breakpoints are NYSE quintiles. We considered the period July 1965-December 1998.[19]

The Cash flows to price portfolios are constructed by grouping stocks into 10 deciles. Portfolios are formed on CF/P at the end of each June, using NYSE breakpoints. The cash flow used in June of year t is total earnings before extraordinary items, plus equity share of depreciation, plus deferred taxes (if available) for the last fiscal year end in *t-1*. P is price times shares outstanding at the end of December of *t-1*. The Earnings to price portfolios and the Dividend Yields to price portfolios are constructed analogously. Portfolios are formed on E/P (D/P) at the end of each June. The earnings used in June of year t are total earnings before extraordinary items for the last fiscal year end in *t-1.* The dividend yield use to form portfolios in June of year t is the total dividends paid from July of *t-1* to June of t per dollar of equity in June of t.

Indexes of Business Cycle.

We use two sets of indexes: NBER Business Cycle Reference Dates (Peaks, Troughs and Peaks-Troughs) and James Stock's Coincident and Leading Indexes and some transformations of them.

In particular, NBERPEAK are the Business Cycle Reference Dates of the Peaks. The index takes value 1 at the peak and zero elsewhere. NBERTROU are the Business Cycle

[19]Fama and French provide 38 portfolios, but given that 5 mostly contain missing data in the sample under consideration, we will use only 33 portfolios.

Reference Dates of the Troughs. The index takes value 1 at the trough and zero elsewhere. NBERDATE are the Business Cycle Reference Dates of the Peaks-Troughs. The index is constructed as the difference of the previous two indexes. NBERCYCL is a linear interpolation of the first two indexes. A value of 1 is attached to NBER peaks, while a value of -1 is attributed to troughs. Peaks and troughs are then joined by linear segments.

XLI is Stock's NBER Experimental Leading Index. It is the forecast of the growth of the Experimental Consumer Index in the following 6 months. XRI is Stock's NBER Experimental Recession Index. It measures the probability that the economy will be in recession in the next 6 months. XLI_2 is Stock's NBER Alternative Non Financial Experimental Leading Index, and XRI_2 is Stocks' NBER Alternative Non Financial Experimental Recession Index.

All these indexes are constructed as forecasts six months ahead. Therefore, to account for possible delay in investors' reactions or misalignment with financial market variables, we construct alternative measures constructed as the $6th$ order lags of Stock's indexes (respectively XLIL6, XLI_2L6, XRIL6 and XRI_2L6). We also consider Stock's Experimental Coincident Recession Index. Given the non-stationarity of such an index, we use two transformations of it, that is, the logarithm of its first differences (XCI_1) and the detrended logarithm (XCI_2).

The Markov-Switching VAR.

To identify the regimes of monetary policy we use a VAR estimation with regime shifts, where the VAR coefficients are not constant throughout the sample period but rather are subject to occasional discrete shifts. The probability law governing these shifts is represented by a two-state Markov chain. In accordance with our model we assume two regimes. The state-space representation of the Markov-switching VAR can be expressed as follows:

$$
\begin{aligned}
y_t &= c_{s_t} + A_{1,s_t} y_{t-1} + ... + A_{p,s_t} y_{t-p} + \varepsilon_t = \\
&= \left(\xi_t' \otimes I\right) \begin{bmatrix} c_1 \\ c_2 \end{bmatrix} + \left(\xi_t' \otimes I\right) \begin{bmatrix} A_{11} \\ A_{12} \end{bmatrix} y_{t-1} + .. + \left(\xi_t' \otimes I\right) \begin{bmatrix} A_{p1} \\ A_{p2} \end{bmatrix} y_{t-p} + \varepsilon_t \\
\xi_t &= F' \xi_{t-1} + \eta_t
\end{aligned}
$$

where: $\xi_t = [1,0]'$ if $s_t = 1$ and $\xi_t = [0,1]'$ if $s_t = 2$ and s_t is an unobserved random variable that takes the values *1* or *2* according to which regime the process is in at time t. $F = \{p_{ij}\}_{i,j=1,2}$ is the transition matrix and p_{ij} is the probability that $s_t = j$ given that $s_{t-1} = i$.

The hypotheses underlying the statistical model are standard: the error term in the observation equation, ε_t, is assumed to be i.i.d. normal, with covariance matrix Σ_{s_t} and η_t is a martingale difference sequence, independent of ε_t and of all available information, past values of s_t included. The VAR is stable in both states. The vector y_t contains five variables: the excess return on the market portfolio, the corresponding dividend yield, the risk-free real rate, CPI inflation and the growth rate of real GDP. The model is estimated by maximum likelihood, using quarterly data covering the period 1965:3-1998:4.[20] An algorithm

[20]The same model was estimated using monthly data as well, but it turned out to be much more

based on the EM principle was employed. Given an ML-estimate of the vector of parameters: $\psi = (c_1', \ c_2', \ vec(A_{11})', \ vec(A_{12})', ..., \ vec(A_{p2})', \ vec(\Sigma_1)', \ vec(\Sigma_2)', \ vec(F)')$. The hidden Markov process is estimated by iterating on the following set of equations:

$$\widehat{\xi}_{t|t} = \frac{\widehat{\xi}_{t|t-1} \odot \eta_t}{1' \left(\widehat{\xi}_{t|t-1} \odot \eta_t \right)}, \ \widehat{\xi}_{t+1|t} = F' \widehat{\xi}_{t|t} \text{ and } \widehat{\xi}_{t|T} = \widehat{\xi}_{t|t} \odot \left\{ F \left[\widehat{\xi}_{t+1|T} \div \widehat{\xi}_{t+1|t} \right] \right\}. \tag{42}$$

where $\widehat{\xi}_{t|t-k} = E(\xi_t | Y_{t-k})$, $Y_t = \{y_1, y_{2,...,} y_t\}$, η_t represents the 2×1 vector whose *i-th* element is the conditional density $f(y_t | s_t = i, Y_{t-1}; \psi)$, 1 is a 2×1 unit vector and the symbols $\odot$ and $\div$ denote element-by-element multiplication and division.

While the index of switches in monetary policy is quarterly, the data on returns are monthly. In order not to waste degrees of freedom, the index is therefore disaggregated to a monthly frequency by applying the method suggested by Chow and Lin (1971), with the inflation rate used as the indicator variable. The method consists of estimating the model using quarterly data, under the assumption that the error term is first-order autocorrelated, and then using the GLS coefficients to estimate the endogenous variable at missing points.

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noisy. The reason is that at higher frequencies it takes too high order a VAR to provide an adequate account of the correlation structure of the data, which inevitably reduces the efficiency of the estimates.

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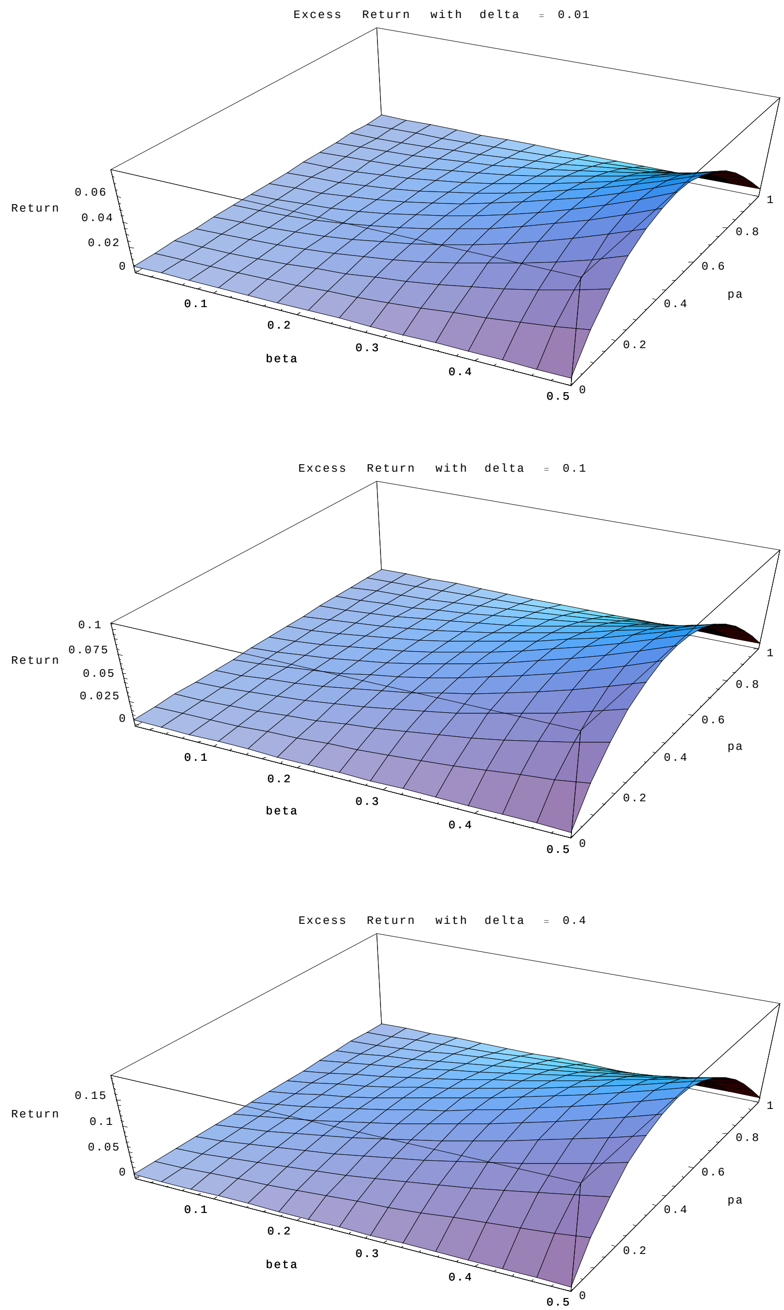

Figure 1: Annual Excess Rates of Returns for different values of the impact of monetary policy on inflation (δ). The excess rate of returns are defined as: $R_t = E_t[\frac{dS^n}{S^n} + \frac{D^n}{S^n} - \frac{dp}{p} - r^n dt]/dt$. The model is calibrated using quarterly data provided by the Federal Reserve Bank of St. Louis for the period January 1965-December 1998. In particular, at a quarterly frequency, $\mu_p = 0.0112$, $\sigma_p = 0.0062$, $\mu_D = 0.0108$, $\sigma_D = 0.023$, $\mu_c = 0.0077$, $\sigma_c = 0.009$, $\sigma_e = \sqrt{\sigma_c^2 - 0.05^2\sigma_{c_D}^2/0.95^2}$, where $\sigma_{c_D} = \sigma_D$, $\gamma = 0.05\beta$, $\rho = 2$ and $\lambda = 0.1987$.

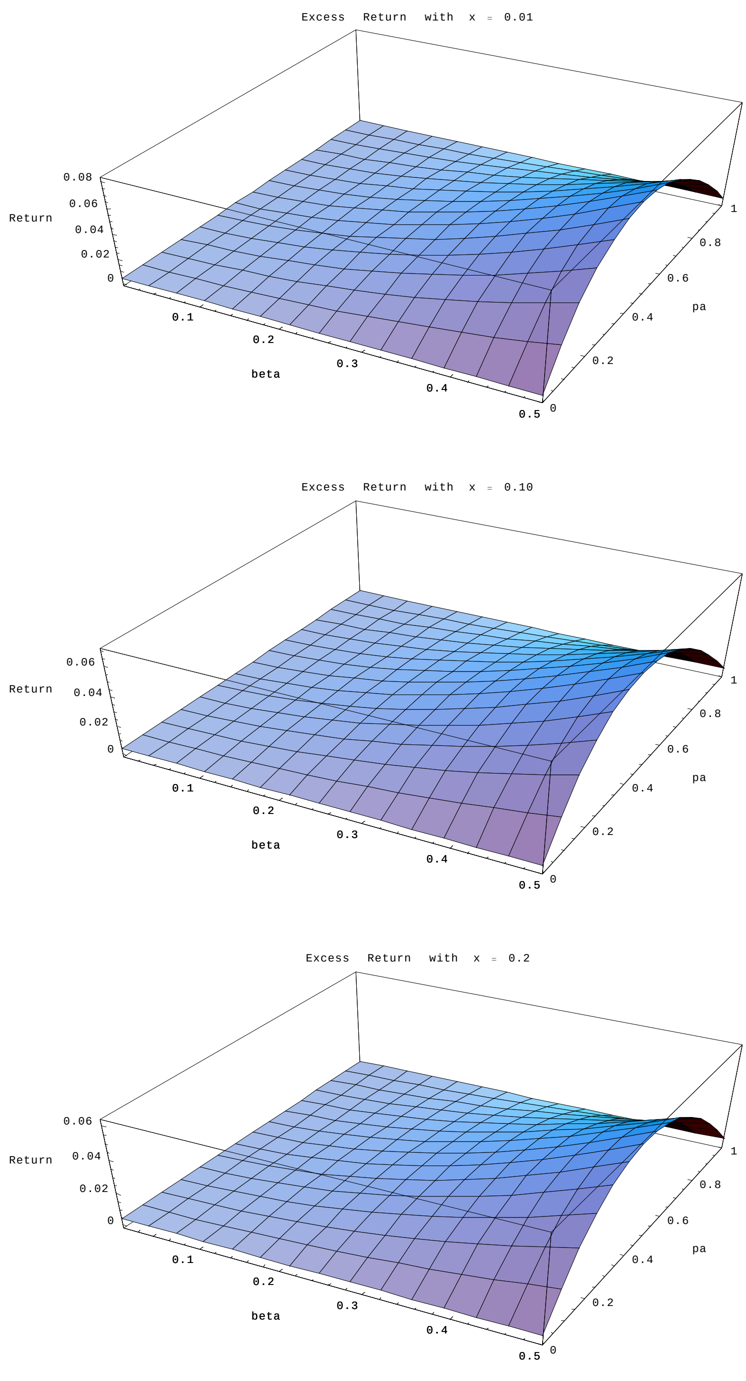

Figure 2: Annual Excess Rates of Returns for different values of the share of dividends over aggregate consumption (x). The excess rate of returns are defined as: $R_t = E_t[\frac{dS^n}{S^n} + \frac{D^n}{S^n} - \frac{dp}{p} - r^n dt]/dt$. The model is calibrated using quarterly data provided by the Federal Reserve Bank of St. Louis for the period January 1965-December 1998. In particular, at quarterly frequency, $\mu_p = 0.0112$, $\sigma_p = 0.0062$, $\mu_D = 0.0108$, $\sigma_D = 0.023$, $\mu_c = 0.0077$, $\sigma_c = 0.009$, $\sigma_e = \sqrt{\sigma_c^2 - x^2\sigma_{c_D}^2/(1-x)^2}$, where $\sigma_{c_D} = \sigma_D$, $\gamma = x\beta$, $\beta = 0.02, \rho = 2$ and $\lambda = 0.1987$.

Figure 3. Perceived regimes of monetary policy and uncertainty.
The figure reports the probability of a non-accommodative monetary policy as perceived by the investors and estimated by using the Markov-Switching VAR. It also reports the uncertainty about the monetary policy, calculated as the product between the probability of tight monetary policy and the complement to one.

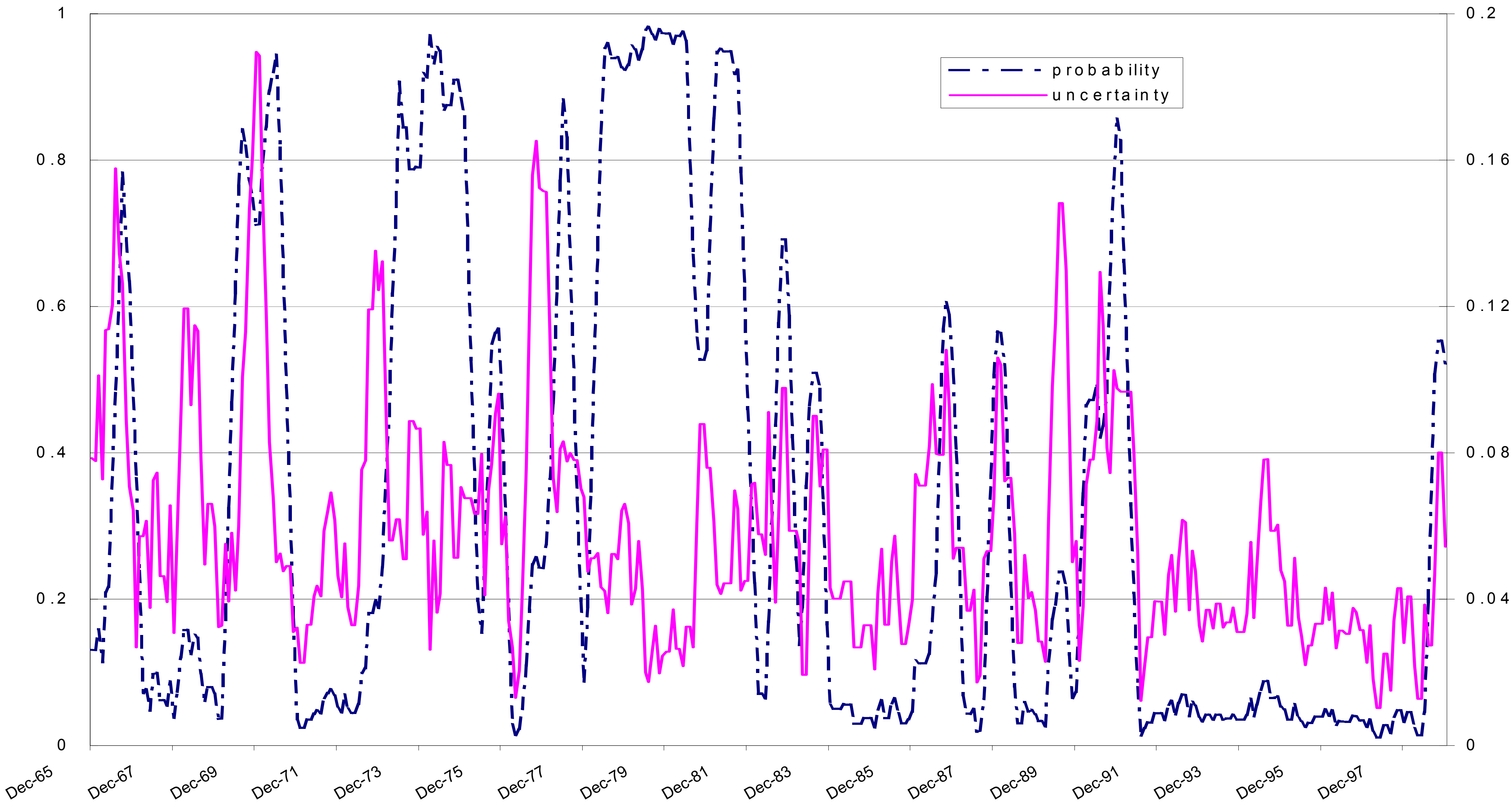

Table 1:
Probability of the Monetary Policy Regime and Business Cycle

The table reports summary statistics about the regression: $\pi_t=\alpha+\beta\Phi_t+\gamma BC_t+\varepsilon_t,$ where π_t is the probability of accommodative monetary policy regime derived from the estimated Markow-switching model; Φ_t is the index of monetary policy stance computed by Bernanke-Mihov and BC is either a busincess cycle index derived from NBER dating or one of James Stock's indices. The index of Bernanke-Mihov increases as the monetary policy becomes more accommodative. The first column indicates which business cycle index has been used in the regression; the second column shows the adjusted R^2 of the regression; the third and fourth ones present, respectively, the estimated coefficient and the corresponding *t*-statistics of the monetary policy index; finally, the last two columns report the point estimate and the t-statistc of the coefficient of the business cycle index. The sample spans the period from January 1961 to December 1996.

Business Cycle index	***Adjusted R^2***	β	t_β	γ	t_γ
NBERCYCL	0.200	2.97	5.14	-0.10	-2.07
NBERDATE	0.202	3.68	9.06	-0.26	-2.20
NBERPEAK	0.200	3.73	9.21	-0.33	-2.00
NBERTROU	0.194	3.78	9.31	0.18	1.11
XLI	0.229	2.87	6.34	0.03	4.26
XLI_2	0.221	3.37	8.14	0.03	3.80
XRI	0.309	2.13	4.95	-0.62	-7.94
XRI_2	0.249	3.27	8.11	-0.86	-5.36
XRI_C	0.219	3.81	9.59	-0.24	-3.66
XCI_1	0.200	3.70	9.10	7.30	2.07
XCI_2	0.262	1.96	3.94	-3.28	-5.94
XLIL6	0.196	3.82	9.48	0.01	1.46
XLI_2L6	0.192	3.86	9.50	0.01	0.77
XRIL6	0.224	3.71	9.36	-0.28	-3.94
XRI_2L6	0.197	3.90	9.62	-0.26	-1.61

Table 2:
Economic tracking portfolio for I_t: regression coefficients and portfolio weights

This table reports results from the following regression: $I_{t+12}=\alpha+\beta \mathbf{B}_t+\chi \mathbf{Z}_{t-1}+u_t$, where $\mathbf{B}_t$ denotes the vector of base assets and $\mathbf{Z}_{t-1}$ the set of control variables. The base assets are two bond portfolios and one equity portfolio. *Term* stands for the spread between the yield on 10-year Treasury bonds and 3-month Treasury bills; *junk* is the difference between Moody's Baa and Aaa corporate yields; *ME1/ME5* is the return on an arbitrage portfolio which is long on stocks of small firms (first NYSE market equity quintile) and short on stocks of big firms (fifth NYSE market equity quintile). Their returns are in excess of the riskless rate. The vector of control variables includes expected inflation (inf^e), actual CPI inflation (*inf*), inflation measured by the year-on-year rate of change of the index of producer prices for finished goods (inf^{ppi}) and the share of household expenditure on durable goods out of total expenditure (*shrdc*). T-values in the last two columns are computed by using the OLS estimator of the covariance matrix of the estimated coefficients in the first case and by using the White estimator in the second case, so as to correct for heteroscedasticity in the residuals.

Regressors	*Coefficients*	*t-statistics (OLS)*	*t-statistics (White)*
	Base assets		
term	-0.397	-2.120	-2.264
junk	32.493	2.642	2.563
ME1/ME5	0.049	2.589	2.510
	Control variables		
$Infl^e$	-12.781	-3.845	-3.670
Infl	3.031	1.530	1.514
$Infl^{ppi}$	0.397	2.187	2.077
exmkt	-0.306	-3.332	-3.188
shrdc	1.082	3.132	3.322

R^2	*0.099*	
Adjusted R^2	*0.080*	
Standard error	*0.072*	
Residual Autocorrelation	*F(12,368)=1.551*	*p-value=0.104*
Heteroschedasticity (linear)	$\chi(8)=27.907$	*p-value=0.001*
Heteroschedasticity (exp.)	$\chi(8)=8.361$	*p-value=0.399*
Current sample	*1965.8-1997.12*	

Table 3: Summary Financial Statistics

Excess returns on 25 book/market and 17 industry portfolios. *MARKET* is the market portfolio and *EXMKT* is the excess return of the market portfolio. The one-month Treasury bill proxies for the riskless rate. The sample covers the period July 1965 - December 1998. Both the sample means and their standard deviations are annualized. ρ_j j=1,2,3,4,12,24, is the sample autocorrelation of order j.

Portfolio	***Mean***	***Std. Dev.***	ρ_1	ρ_2	ρ_3	ρ_4	ρ_{12}	ρ_{24}
Panel A: Size and book-to-market portfolios								
S1/B1	1.888	26.484	0.234	0.018	-0.011	0.002	0.054	-0.023
S1/B2	8.703	23.119	0.226	-0.002	-0.025	-0.002	0.065	-0.016
S1/B3	8.887	20.943	0.221	0.005	-0.012	-0.028	0.090	0.013
S1/B4	11.551	19.771	0.224	-0.013	-0.015	-0.020	0.124	-0.011
S1/B5	12.795	20.857	0.248	-0.006	-0.024	-0.034	0.178	0.053
S2/B1	4.907	25.228	0.168	-0.036	-0.053	-0.039	-0.016	-0.036
S2/B2	7.725	21.157	0.183	-0.031	-0.036	-0.042	0.041	0.004
S2/B3	10.546	19.080	0.184	-0.030	-0.029	-0.021	0.048	-0.035
S2/B4	11.385	18.000	0.171	-0.041	-0.029	-0.009	0.092	0.009
S2/B5	12.280	19.906	0.160	-0.067	-0.063	-0.041	0.135	0.026
S3/B1	5.449	23.173	0.144	-0.026	-0.036	-0.064	-0.008	-0.044
S3/B2	8.589	19.240	0.174	-0.012	-0.001	-0.060	0.014	-0.003
S3/B3	8.421	17.540	0.155	-0.039	-0.039	-0.045	0.012	-0.018
S3/B4	10.334	16.498	0.161	-0.023	-0.004	-0.038	0.051	0.032
S3/B5	11.585	18.850	0.153	-0.075	-0.067	-0.029	0.095	-0.007
S4/B1	6.157	20.235	0.107	-0.027	-0.026	-0.057	-0.021	-0.036
S4/B2	5.421	18.488	0.128	-0.028	-0.032	-0.026	-0.028	-0.011
S4/B3	8.436	17.104	0.080	-0.026	-0.014	-0.072	0.003	-0.008
S4/B4	9.736	16.184	0.082	0.000	0.001	-0.062	0.055	0.013
S4/B5	11.127	18.887	0.044	-0.035	-0.019	-0.020	0.035	0.002
S5/B1	6.248	16.771	0.055	-0.002	0.005	-0.018	0.056	-0.012
S5/B2	5.965	16.111	0.036	-0.060	-0.002	0.007	-0.002	-0.020
S5/B3	6.067	15.162	-0.034	-0.052	0.007	-0.035	-0.012	0.019
S5/B4	7.839	14.822	-0.055	0.008	0.064	-0.084	0.035	0.022
S5/B5	8.601	16.184	0.021	-0.007	-0.039	0.003	0.046	0.012
MARKET	12.607	15.475	0.054	-0.039	-0.011	-0.033	0.019	-0.012
EXMKT	6.259	15.547	0.060	-0.034	-0.009	-0.031	0.016	-0.015
Panel B: Industry Portfolios								
Food	8.559	15.970	0.067	-0.060	0.001	-0.023	0.070	-0.049
Mines	4.457	22.527	0.047	-0.011	-0.017	-0.057	-0.028	0.060
Oil	6.854	18.305	-0.013	-0.040	0.022	0.020	0.004	-0.043
Clths	5.493	21.358	0.236	0.045	-0.032	-0.059	0.068	-0.046
Durbl	6.992	18.855	0.107	0.046	0.002	-0.027	0.033	-0.008
Chems	5.319	18.533	0.013	-0.052	0.044	-0.013	-0.038	0.024
Cnsum	9.718	16.946	0.019	-0.005	-0.054	0.004	0.100	-0.002
Cnstr	7.136	20.499	0.109	-0.042	-0.025	-0.073	0.027	-0.003
Steel	2.576	21.235	-0.004	-0.055	-0.081	-0.014	-0.100	0.087
FabPr	5.879	18.165	0.153	-0.061	-0.038	-0.052	0.023	-0.006
Machn	6.314	19.937	0.097	0.008	-0.013	-0.051	0.015	0.053
Cars	5.529	20.317	0.132	-0.017	-0.018	-0.050	0.026	-0.031
Trans	6.411	20.909	0.124	-0.006	-0.087	0.044	-0.003	0.029
Utils	4.215	13.699	0.017	-0.108	0.011	0.029	0.044	0.020
Rtail	7.702	19.827	0.170	0.006	-0.073	-0.054	0.035	-0.061
Finan	8.099	17.913	0.126	-0.042	-0.037	-0.017	0.037	-0.051
Other	6.554	16.370	0.049	-0.038	-0.008	-0.075	-0.013	0.005
MARKET	12.607	15.475	0.054	-0.039	-0.011	-0.033	0.019	-0.012
EXMKT	6.259	15.547	0.060	-0.034	-0.009	-0.031	0.016	-0.015

Table 4: Expected Inflation and Excess Returns

Size and book-to-market portfolio excess returns are regressed on a constant and the proxy for expected inflation derived from the estimated Markov-switching model. The first column shows the adjusted R^2 of the model while the second one reports value of the regression coefficient of expected inflation. The last column reports the *t*-statistic for testing whether the expected inflation parameter is statistically significant. To correct for the bias due to the presence of a generated regressor, White standard errors have been used. The sample period is July 1965-December 1998. Returns are in excess of the 30-day Treasury bill.

Portfolio	***Adjusted R^2***	***Expected Inflation***	
		coefficient	*t-stat*
Panel A: Size and book-to-market portfolios			
S1/B1	0.011	-3.761	-1.996
S1/B2	0.020	-4.201	-2.596
S1/B3	0.019	-3.728	-2.521
S1/B4	0.024	-3.909	-2.905
S1/B5	0.023	-4.032	-2.693
S2/B1	0.013	-3.849	-2.171
S2/B2	0.017	-3.583	-2.386
S2/B3	0.027	-3.984	-2.850
S2/B4	0.025	-3.648	-2.816
S2/B5	0.018	-3.479	-2.437
S3/B1	0.018	-4.069	-2.546
S3/B2	0.022	-3.630	-2.631
S3/B3	0.027	-3.670	-2.816
S3/B4	0.031	-3.668	-3.029
S3/B5	0.021	-3.549	-2.410
S4/B1	0.021	-3.790	-2.617
S4/B2	0.024	-3.657	-2.802
S4/B3	0.019	-3.028	-2.380
S4/B4	0.032	-3.658	-3.142
S4/B5	0.022	-3.633	-2.601
S5/B1	0.051	-4.730	-4.230
S5/B2	0.035	-3.819	-3.456
S5/B3	0.033	-3.498	-3.330
S5/B4	0.029	-3.195	-3.044
S5/B5	0.043	-4.195	-3.878
Panel B: Industry market portfolios			
Food	0.039	-3.899	-4.110
Mines	0.001	-1.534	-1.122
Oil	0.014	-2.818	-2.532
Clths	0.020	-3.865	-2.992
Durbl	0.055	-5.462	-4.855
Chems	0.023	-3.615	-3.200
Cnsum	0.035	-3.971	-3.872
Cnstr	0.017	-3.493	-2.802
Steel	0.008	-2.636	-2.034
FabPr	0.020	-3.228	-3.009
Machn	0.036	-4.663	-3.928
Cars	0.040	-5.030	-4.151
Trans	0.023	-4.051	-3.196
Utils	0.019	-2.438	-2.907
Rtail	0.029	-4.263	-3.567
Finan	0.034	-4.079	-3.806
Other	0.030	-3.511	-3.623

TABLE 5: Evidence of pricing

This table reports the Generalized Method of Moments tests of the moment conditions of equations 17-20 in the text. We consider the standard Fama and French factors (Panels A and B) and the "orthogonalized" Φ_t factor (Panels C and D), where the monetary policy uncertainty factor (Φ_t) has been previously orthogonalized by regressing it on the Fama and French factors. Panels A and C report the estimates for 25 book-to-market and size portfolios, while Panels B and D report the estimates for 17 industry portfolios. The vectors, δ, ϕ_{MKT}, ϕ_{HML}, ϕ_{SMB}, $\phi_{\Phi t}$, contain the coefficients of the linear relationship between λ, λ_{MKT}, λ_{HML}, λ_{SMB}, $\lambda_{\Phi t}$ and the vector of instruments, **Z**. The instrumental variables are a constant, one month T-bill yield (*T-bill*), dividend yield of the S&P 500 index (*Div*), term premium – spread between a 10 years and 1year Treasury bond yield (*Term*), junk premium – spread between Moody's Baa and Aaa corporate bond yields (*Junk*), difference between the one month returns of a three month and one month T-bill (*Hb3*) and a January dummy that takes value 1 for January and 0 otherwise. We report the estimated coefficients as well as the *t-stat*. Last rows of each panel reports the test for overidentifying restrictions and the Wald test for the significance of the $\phi_{\Phi t}$ coefficients. The value of the χ^2 statistic, the degrees of freedom and the *p-value* are reported. The coefficients for the dividend yield (*Div*), the difference between the one month returns of a three month and one month T-bill (*Hb3*), the Treasury Bill (*T-bill*) and the junk premium (*Junk*) have been divided by 100.

Non-orthogonalized factors

Panel A: Book-to-market and size portfolios

	δ		ϕ_{MKT}		ϕ_{HML}		ϕ_{SMB}		ϕ_{Φ}	
	Mean	*t-test*	*Mean*	*t-test*	*Mean*	*t-test*	*Mean*	*t-test*	*Mean*	*t-test*
Constant	0.84	1.73	1.33	0.27	51.72	6.27	49.94	4.77	-57.92	-2.97
Div	17.46	6.38	-120.72	-4.70	-174.03	-4.18	392.40	7.68	-709.50	-6.49
Junk	-55.87	-7.68	155.19	3.09	35.65	0.41	-717.43	-9.18	1992.41	10.03
Term	50.35	7.17	-649.59	-11.84	499.78	5.20	698.94	5.91	-2223.51	-9.41
Hb3	-1.18	-2.90	17.70	5.35	51.18	8.09	12.45	2.19	3.05	0.26
T-bill	-4.45	-4.62	52.98	6.00	17.32	1.44	-214.24	-9.97	204.66	6.40
Dummy$_{JANUARY}$	-7.67	-11.95	-22.11	-5.13	87.53	10.66	110.82	11.08	-61.28	-2.96

Overidentifying restrictions test: $\chi^2 = 61.65$; degrees of freedom: 147; *p-value*: 0.99.

Wald test: $\chi^2 = 323.11$; degrees of freedom:7; *p-value*: 0.00.

Panel B: Industry portfolios

	δ		ϕ_{MKT}		ϕ_{HML}		ϕ_{SMB}		ϕ_{Φ}	
	Mean	*t-test*	*Mean*	*t-test*	*Mean*	*t-test*	*Mean*	*t-test*	*Mean*	*t-test*
Constant	5.33	7.33	5.48	0.90	-1.79	-0.17	11.27	0.67	-128.60	-4.93
Div	-33.01	-7.48	-25.60	-0.98	193.09	2.97	248.96	4.02	1215.85	8.11
Junk	12.65	1.18	228.21	3.95	425.35	3.06	-665.45	-4.73	-1240.16	-4.07
Term	-15.87	-1.95	72.43	0.88	613.22	5.21	-199.71	-1.03	686.83	2.30
Hb3	4.03	6.03	-0.74	-0.12	4.18	0.31	66.77	6.15	-133.77	-6.98
T-bill	-0.10	-0.08	-11.27	-0.99	-201.36	-9.34	-171.29	-7.00	-34.42	-0.83
Dummy$_{JANUARY}$	0.33	0.50	-12.77	-2.37	29.82	2.61	-12.81	-1.02	-46.37	-2.09

Overidentifying restrictions test: $\chi^2 =49.09$; degrees of freedom: 91; *p-value*: 0.99.

Wald test: $\chi^2 = 237.81$; degrees of freedom:7; *p-value*: 0.00.

Orthogonalized Φt factor

Panel C: Book-to-market and size portfolios

	δ		ϕ_{MKT}		ϕ_{HML}		ϕ_{SMB}		ϕ_{Φ}	
	Mean	*t-test*	*Mean*	*t-test*	*Mean*	*t-test*	*Mean*	*t-test*	*Mean*	*t-test*
Constant	0.84	1.73	-1.64	-0.31	38.35	3.60	23.16	3.06	-57.92	-2.97
Div	17.46	6.38	-157.21	-5.32	-337.88	-6.58	64.34	2.48	-709.51	-6.49
Junk	-55.86	-7.68	257.62	4.71	495.73	5.18	203.76	2.73	1992.41	10.03
Term	50.35	7.17	-763.90	-12.45	-13.76	-0.12	-329.19	-3.35	-2223.41	-9.41
Hb3	-1.18	-2.90	17.86	5.20	51.88	6.46	13.86	2.76	3.05	0.26
T-bill	-4.45	-4.61	63.50	6.49	64.58	4.97	-119.61	-9.71	204.64	6.40
Dummy$_{JANUARY}$	-7.67	-11.95	-25.26	-5.68	73.39	8.16	82.49	11.49	-61.28	-2.96

Overidentifying restrictions test: χ^2 = 61.35; degrees of freedom: 147; *p-value*: 1.

Wald test: χ^2 =320.04 ; degrees of freedom: 7; *p-value*: 0.00.

Panel D: Industry portfolios

	δ		ϕ_{MKT}		ϕ_{HML}		ϕ_{SMB}		ϕ_{Φ}	
	Mean	*t-test*	*Mean*	*t-test*	*Mean*	*t-test*	*Mean*	*t-test*	*Mean*	*t-test*
Constant	5.33	7.33	-1.13	-0.17	-31.49	-2.23	-48.18	-3.42	-128.59	-4.93
Div	-33.01	-7.48	36.90	1.31	473.86	5.94	811.12	12.37	1215.82	8.11
Junk	12.65	1.18	164.42	2.77	138.94	0.90	-1238.86	-8.63	-1240.11	-4.07
Term	-15.87	-1.95	107.75	1.26	771.83	5.65	117.86	0.83	686.86	2.30
Hb3	4.03	6.03	-7.62	-1.22	-26.70	-1.70	4.92	0.50	-133.77	-6.98
T-bill	-0.10	-0.08	-13.04	-1.12	-209.31	-8.51	-187.21	-6.98	-34.42	-0.83
Dummy$_{JANUARY}$	0.33	0.50	-15.16	-2.68	19.11	1.46	-34.24	-4.40	-46.36	-2.09

Overidentifying restrictions test: χ^2 = 49.09; degrees of freedom: 91; *p-value*: .99.

Wald test: χ^2 = 237.81; degrees of freedom:7; *p-value*: 0.00.

Table 6: Expected Inflation and monetary uncertainty

Different groupings of portfolio excess returns are regressed on a constant, the three Fama-French risk factors ($\boldsymbol{F}_t$), the tracking portfolio mimicking monetary policy uncertainty (Φ_t) and the proxy for expected inflation derived from the estimated Markov-switching model ($Infl^e_t$). We consider the 25 size and book-to-market portfolios (Panel A), the 17 industry portfolios (Panel B), cash flow-to-price portfolios (Panel C), earnings-to-price portfolios (Panel D) and dividend-to-price portfolios (Panel E). In the case of Cash flows to price portfolios (CF/P), cash flow is the cash flow at the last fiscal year end of the prior calendar year, while price is represented by the market capitalization (ME) at the end of December of the prior year. In the case of earnings-to-price, we consider the excess returns on portfolios formed on deciles of the distribution of E/P, where E/P are the earnings before extraordinary at the last fiscal year end of the prior calendar year divided by ME at the end of December of the prior year. In the case of dividends-to-price portfolios, we consider the excess returns on portfolios formed on deciles of the distribution of D/P, where D/P is the dividend yield. In all the cases stocks are grouped into 10 deciles.

The first column shows the adjusted R^2 of the model. The subsequent two columns present, respectively, the point vale and the *t-statistic* for the coefficient on the tracking portfolio. The last two columns report the corresponding evidence for the expected inflation parameter. Due to the presence of a generated regressor, the error term in the equation in not homoskedastic. To correct for the bias in the OLS estimate of the covariance matrix of the estimated coefficients, White standard errors have been used. The sample spans the period from July 1965 to December 1998. Returns are measured in excess of the return on a 30-day Treasury bill.

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$$\text{Regression Model: } R_{i,t} = \alpha_i + \delta_i' \mathbf{F}_t + \gamma_i(\Phi_t) + \beta_i Infl^e_t + \varepsilon_{i,t}$$

Portfolio	***Adjusted R^2***	***Tracking Portfolio***		***Expected Inflation***	
		coefficient	***t-stat***	***coefficient***	***t-stat***
Panel A: Size and book-to-market portfolios					
S1/B1	0.931	0.799	9.867	0.436	1.001
S1/B2	0.954	0.802	16.182	-0.579	-1.957
S1/B3	0.962	0.821	21.300	-0.472	-1.808
S1/B4	0.959	0.753	18.547	-0.842	-3.217
S1/B5	0.957	0.805	18.594	-0.797	-2.707
S2/B1	0.955	0.497	9.275	0.899	2.540
S2/B2	0.959	0.603	12.977	0.292	0.973
S2/B3	0.954	0.503	10.990	-0.424	-1.576
S2/B4	0.946	0.446	10.119	-0.068	-0.229
S2/B5	0.953	0.546	11.521	0.428	1.473
S3/B1	0.949	0.419	7.843	0.591	1.755
S3/B2	0.938	0.483	9.499	0.114	0.356
S3/B3	0.925	0.353	7.354	0.018	0.054
S3/B4	0.926	0.367	7.701	-0.230	-0.666
S3/B5	0.918	0.407	7.042	0.422	1.110
S4/B1	0.943	0.228	4.692	0.600	2.090
S4/B2	0.915	0.316	5.894	0.499	1.356
S4/B3	0.915	0.236	4.342	1.005	2.853
S4/B4	0.897	0.270	4.530	0.097	0.230
S4/B5	0.877	0.473	6.902	0.423	1.066
S5/B1	0.932	0.126	2.612	-0.836	-2.400
S5/B2	0.918	0.118	2.341	0.162	0.525
S5/B3	0.859	-0.064	-1.087	0.439	1.067
S5/B4	0.891	0.151	2.696	0.635	1.864
S5/B5	0.809	0.267	3.696	-0.657	-1.321
Panel B: Industry portfolios					
Food	0.746	0.219	2.680	-0.671	-1.295
Mines	0.550	0.530	3.448	1.971	2.023
Oil	0.541	0.189	1.481	0.504	0.626
Clths	0.796	0.822	8.325	-0.459	-0.735
Durbl	0.798	0.358	4.101	-1.776	-3.214
Chems	0.768	0.377	4.079	0.238	0.407
Cnsum	0.754	-0.046	-0.529	-0.411	-0.749
Cnstr	0.888	0.272	3.867	1.292	2.897
Steel	0.650	0.443	3.438	1.391	1.703
FabPr	0.811	0.294	3.717	0.525	1.049
Machn	0.809	0.411	4.633	-0.991	-1.765
Cars	0.623	0.630	4.948	-1.750	-2.170
Trans	0.814	0.328	3.531	0.415	0.706
Utils	0.576	-0.098	-1.061	0.593	1.013
Rtail	0.743	0.565	5.482	-0.779	-1.193
Finan	0.866	-0.091	-1.363	0.633	1.492
Other	0.938	0.188	4.570	0.318	1.223

Regression Model: $R_{i,t} = \alpha_i + \delta'_i F_t + \gamma_i(\Phi_t) + \beta_i Infl^e_t + \varepsilon_{i,t}$

Portfolio	***Adjusted R^2***	***Tracking portfolio***		***Expected Inflation***	
		coefficient	***t-test***	***coefficient***	***t-test***
Panel C: Cash flows-to-price portfolios (CF/P)					
Decile 1	0.924	0.170	2.900	-0.530	-1.400
Decile 2	0.926	0.174	3.561	-0.523	-1.446
Decile 3	0.913	0.139	2.549	0.207	0.577
Decile 4	0.918	0.093	1.775	0.532	1.535
Decile 5	0.890	0.205	3.577	1.005	2.732
Decile 6	0.898	0.068	1.255	0.228	0.621
Decile 7	0.876	0.154	2.760	0.422	1.135
Decile 8	0.868	0.211	3.583	-0.009	-0.020
Decile 9	0.867	0.299	4.091	-0.237	-0.563
Decile 10	0.889	0.325	4.976	-0.029	-0.064
Panel D: Earnings-to-price portfolios (E/P)					
Decile 1	0.905	0.277	4.314	-0.860	-2.376
Decile 2	0.938	0.100	2.176	0.368	1.345
Decile 3	0.915	0.208	3.962	0.320	0.887
Decile 4	0.894	0.114	1.929	0.396	1.060
Decile 5	0.911	0.157	3.336	0.600	1.841
Decile 6	0.894	0.118	1.774	0.667	1.798
Decile 7	0.889	0.148	2.909	0.305	0.934
Decile 8	0.875	0.163	2.743	-0.175	-0.372
Decile 9	0.886	0.285	4.361	-0.475	-1.307
Decile 10	0.894	0.264	4.347	-0.224	-0.483
Panel E: Dividends-to-price portfolios (D/P)					
Decile 1	0.918	0.179	2.885	0.458	1.162
Decile 2	0.922	0.198	3.955	0.331	0.951
Decile 3	0.929	0.147	2.870	-0.124	-0.374
Decile 4	0.924	0.114	2.053	0.242	0.690
Decile 5	0.908	0.170	3.232	0.435	1.147
Decile 6	0.896	0.160	2.964	0.550	1.605
Decile 7	0.898	0.090	1.717	0.596	1.848
Decile 8	0.873	0.196	3.265	0.521	1.531
Decile 9	0.827	0.167	2.495	-0.149	-0.368
Decile 10	0.683	0.240	2.493	-1.092	-1.731