Risk and Return Reaction of the Stock Market to Public Announcements about Fundamentals: Theory and Evidence

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Abstract

The paper analyzes how the stock market reacts to news about fundamentals. Specifically, we analyze how the stock market reacts to scheduled public macroeconomic announcements that reveal information about the state of the economy. Recently, among other studies, Boyd, Hu, and Jagannathan (2005) find that the stock market reacts negatively to positive news about the state of the economy. In this paper, we provide a theoretical explanation for recent empirical findings about the effect of news on the stock market. We develop a dynamic general equilibrium asset pricing model where investors learn about the unobserved state of the economy through dividend realizations and periodic public announcements. In this framework, we find that returns react significantly on announcement days only if there is a significant change in investors' beliefs due to the announcement. Furthermore, positive unanticipated news about the state of the economy decreases the stock market return on announcement days if investors are more risk averse than log utility. The stock market reacts asymmetrically to unanticipated news. In other words, the effect of a positive unanticipated news is stronger than the effect of a negative unanticipated news of the same magnitude. On the other hand, the conditional volatility of returns reacts to the resolution of uncertainty on announcement days. The higher the degree of uncertainty resolved on the announcement day, the smaller the conditional volatility will be. We claim that the resolution of uncertainty about the state of the economy is the main theoretical link between news about fundamentals and the behavior of conditional volatility on announcement days. Additionally, we find that the information revealed on announcement days is incorporated into the stock price in a single period. Using real-time data, we develop model-based and survey-based measures of unanticipated news and uncertainty to test the implications of our model. We find supporting evidence for our theoretical model in the aggregate stock market data.

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1 Introduction

Investors are constantly faced with the arrival of new information, such as macroeconomic releases, earnings and dividends announcements, political news etc. Such news lead investors to update their expectations about the fundamentals of the economy. The effect of news on stock returns is central to financial decision making. Investors need to know how return dynamics are affected by news for portfolio allocation, risk management and pricing options. The response of returns to news such as monetary policy decisions (e.g. FOMC meetings) conveys important information for policy makers. Furthermore, the effect of news on the stock market return has important implications for factor models used in security valuation. More importantly, the concept of market efficiency is closely related to the reaction of stock returns to news. Analyzing effects of public announcements on returns might shed some light on market efficiency. It is clear that the change in investors' expectations affect the stock market. This fact that new information affects not only the mean of stock returns but also the conditional volatility is well documented in the finance literature (Boyd, Hu, and Jagannathan (2005), Flannery and Protopapadakis (2002), Bernanke and Kuttner (2003), Bomfim (2003)). In contrast with the remarkable progress made in modeling stock returns to account for the empirical facts, little is known about the theoretical relation between the fundamentals and the reaction of returns to news.

The difficulty in analyzing the effect of news on return dynamics is that we do not directly observe information arrivals. It is difficult to accurately measure the information content and uncertainty about unscheduled news. On the other hand, analysis of public announcement effects provides a good starting point. First of all, the timing of macroeconomic news is exogenously determined and publicly known. Secondly, it is relatively easy to quantify investors' expectations about scheduled macroeconomic announcements by employing model-based or survey-based measures. Scheduled announcements are released on a periodic basis, thus, information arrivals are neither in clusters, nor positively correlated. Analyzing the reaction of stock returns to public macroeconomic announcements might provide intuition about the reaction of returns to other types of scheduled announcements, such as earnings announcements. Furthermore, recent empirical findings suggest that the stock market reacts differently to scheduled and unscheduled announcements. Effects observed for scheduled announcements such as the calm-before-the-storm effect[1] are not observed for unscheduled announcements. Analyzing the stock market's reaction to macroeconomic announcements might provide intuition about different effects of scheduled and unscheduled news on return dynamics.

Although there is strong empirical evidence that public announcements about fundamentals affect both the mean and conditional volatility of returns on announcement days, several questions still remain about the theoretical link between public announcements and the behavior of stock returns. A formal model is crucial not only for analyzing the theoretical link but also for constructing reasonable proxies for investors' expectations and uncertainty about the announcement. Instead of the current practice of using either ad hoc forecasting models or surveys, a formal model provides guidelines on how to construct such proxies for market expectations about announcements.

The finance literature on the effect of news on the mean of stock returns is relatively limited compared to the literature on the effect of news on volatility. In a recent paper, Boyd, Hu, and Jagannathan (2005) find that unemployment news have asymmetric

[1] Jones, Lamont, and Lumsdaine (1998) find empirical evidence of relatively low conditional volatility of returns before major scheduled macroeconomic announcements. They dubbed this empirical fact the "calm-before-the-storm" effect.

effects on the mean S&P 500 returns depending on the state of the economy. Unanticipated news in unemployment announcements seems to affect stock returns positively in contractions and negatively in expansions. They suggest three different channels through which the information content of unemployment news affects stock returns. Unemployment news reveals unanticipated information about future interest rates, the equity risk premium, and corporate earnings or dividends. McQueen and Roley (1993) find a strong relation between stock returns and macroeconomic news surprises, such as inflation, industrial production, and unemployment news. Flannery and Protopapadakis (2002) use a GARCH model of daily equity returns in which both realized returns and their conditional volatility are allowed to vary with 17 macroeconomic series' announcements. Of these 17 macroeconomic announcements, they identify three nominal variables (CPI, PPI, and Money Aggregate-M1 or M2) and three real variables (Employment Report, Balance of Trade, and Housing Starts) as possible candidates for risk factors. They find that the two nominal variables that affect the level of returns are CPI and PPI. Bernanke and Kuttner (2003) analyze the effect of unanticipated changes in the federal funds rate target on value-weighted portfolio of all assets in the Center for Research in Security Prices (CRSP) universe. They find that an unanticipated rate cut of 25 basis points increases the level of stock prices by approximately 1 percent. Employing the decomposition of Campbell (1991), they find that most of the effect of monetary policy on stock prices can be traced to its implications for forecasted equity risk premiums. Among other studies, Balduzzi, Elton, and Green (1999), Fleming and Remolona (1999) and Andersen, Bollerslev, Diebold, and Vega (2003) find important effects of inflation news (CPI and PPI) on other types of assets such as bonds and exchange rates. The stylized fact from this strand of literature is that returns react to the surprise content of news. Stock returns react to the announcement strongly when one controls for the anticipated content of the news. Furthermore, the stock market reacts negatively to positive unanticipated news and this reaction is stronger for positive unanticipated news than negative ones.

There is ample evidence on the effect of news on return volatility. Recently, Flannery and Protopapadakis (2002) and Bomfim (2003) find strong evidence of effects of macroeconomic announcements on the volatility of the stock market returns. Flannery and Protopapadakis (2002) analyze daily conditional volatility of value-weighted NYSE-AMEX-NASDAQ market index from CRSP between January 1980 and December 1996. They find that the conditional volatility reacts to announcements about the money supply, and three real variables (Employment Report, Balance of Trade, and Housing Starts). Bomfim (2003) analyzes the pre-announcement and news effects on the stock market in the context of public disclosure of monetary policy decisions. He finds that the stock market tends to be relatively quiet, conditional volatility is abnormally low, on days preceding regularly scheduled policy announcements. Jones, Lamont, and Lumsdaine (1998) examine the reaction of conditional volatility implied by ARCH models to news releases in the Treasury bond market. They find a risk premium on the release dates and a lack of persistence of announcement-day volatility. Furthermore, they find that the volatility of returns decreases significantly before the announcement day and dub this empirical fact as the "calm-before-the-storm". Li and Engle (1998) examined the heterogeneity in the degree of persistence between scheduled macroeconomic announcement days and non-announcement days in the Treasury futures market. They find that scheduled and unscheduled macroeconomics announcements have different effects on the conditional volatility of returns. Specifically, scheduled announcements have less persistent effects on conditional volatility. Among other studies, Andersen and Bollerslev (1998), Andersen, Bollerslev, Diebold, and Vega (2003) and Faust, Rogers, Wang, and Wright (2003) find strong evidence of effects of macroeconomic announcements on the volatility of several different assets. The stylized facts from this strand of literature are the relatively low persistence of stock volatility after an announcement and the calm-before-the-storm effect. Additionally, the effect of news is relatively different when one distinguishes between scheduled and unscheduled announcements. The literature suggests two possible channels that news affects the conditional volatility of asset returns: clustered news arrival and heterogeneity of information across market participants. In this paper, we suggest that the conditional volatility on scheduled announcement days reacts to the resolution of uncertainty about the growth rate of the economy.

Although there is evidence that asset returns respond to new macroeconomic information, little is known about the link between announcements about fundamentals and the stock market's reaction. Kim and Verrecchia (1991) develop a three-period partial equilibrium model to analyze the market reaction to anticipated announcements. They conclude that a price change reflects the change in investors' expectations due to the arrival of new information, whereas volume arises due to information asymmetries. Veronesi (1999) finds that conditional volatility of returns is a function of investors' uncertainty about the state of the economy. He finds that this effect results in asymmetric reaction of returns to news. However, neither of them test the implications of their models.

The contribution of the paper is twofold. First, we develop a general equilibrium asset pricing model to describe the theoretical link between fundamentals and the stock market's reaction to public news announcements. Specifically, we develop an asset pricing model where investors learn about the future growth rate of the economy through dividend realizations and regularly scheduled public announcements. In the general equilibrium framework, the effect of news about fundamentals on the stochastic discount factor and the growth rate of the economy are closely linked. This fact not only simplifies our analysis and makes it analytically tractable but also allows us to focus on one type of macroeconomic announcements, namely the Gross Domestic Product (GDP) releases. It is relatively straightforward to develop model-based measures of unanticipated news and uncertainty in our model. Furthermore, due to the learning component, our model is capable of generating empirical facts such as time-varying volatility and expected returns. In a simplified version of the model, we analyze the effect of a single announcement that resolves the uncertainty in the economy. In this simplified framework, we derive testable implications of our model.

Analyzing the implied return equation on announcement days, the implications of our model can be summarized as follows: In line with the existing literature, we find that the mean return on announcement days is a function of unanticipated news. That is, it reacts to the surprise content of the announcement[2]. The mean return on announcement days is significantly different from the mean return on non-announcement days if there is a significant surprise that is not already incorporated into investors' beliefs. This reaction to unanticipated news is negative if investors are more risk averse than a log-utility investor. In other words, returns react negatively (positively) to positive (negative) unanticipated news when investors are more risk averse than log utility. The intuition behind this result is straightforward. In a power utility framework, the risk aversion parameter is closely tied to the intertemporal elasticity of substitution[3], which measures how willing investors are to substitute consumption across time[4]. Unantici-

[2]In this paper, we use the terms "unanticipated news" and "surprise" interchangeably.

[3]In a power utility framework, the reciprocal of the risk aversion parameter is the intertemporal elasticity of substitution.

[4]It is the interpretation of this parameter as the intertemporal elasticity of substitution that drives this result, not the interpretation of risk aversion.

pated positive news about the state of the economy has two effects on the equilibrium asset price: income and substitution effects. An unanticipated higher growth rate increases future consumption, hence the asset price which is a claim on future consumption. On the other hand, investors are willing to consume more in the current period which decreases the current equilibrium asset price due to the increase in the stochastic discount factor. The reaction of the price to news depends on which effect dominates in equilibrium which in turn depends on the risk aversion parameter. If investors are more risk averse than a log-utility investor, the substitution effect dominates the income effect. Hence, a positive surprise about the growth rate of the economy has a negative effect on the equilibrium return of the risky asset. The magnitude of the reaction depends on the risk aversion of the representative investor and the size of surprise in the announcement. Furthermore, we find that the reaction of equilibrium returns to unanticipated news about the growth rate of the economy is asymmetric. A positive unanticipated news affects the mean stock return more than a negative unanticipated news of the same magnitude. On the other hand, in line with Veronesi (1999), we find that the conditional volatility of returns on both announcement and non-announcement days is a function of investors' uncertainty. Differently, we derive a closed form solution for the conditional volatility of returns on announcement days. Furthermore, we find that the effect of uncertainty on the conditional volatility is sensitive to investors' risk aversion. We claim that it is the resolution of uncertainty on announcement days that causes the conditional volatility to behave differently relative to non-announcement days. The higher the degree of uncertainty resolved on the announcement day, the smaller the conditional volatility will be. The resolution of uncertainty about the state of the economy is the main theoretical link between news about fundamentals and the behavior of conditional volatility on announcement days. Finally, in line with the efficient market hypothesis, we find that the information revealed on announcement days is incorporated into the equilibrium price in one period.

Secondly, we develop model-based and survey-based measures of unanticipated news and uncertainty about the announcement. We test the implications of our model for advance GDP announcements using a simple GARCH framework for daily returns with these constructed measures. The empirical results provide supporting evidence for our model and can be summarized as follows: The effect of unanticipated news on stock returns is negative and robust across different measures. In other words, unanticipated positive (negative) news about GDP decreases (increases) the mean return on advance GDP announcement days. Since advance GDP estimates are released on announcement days before the stock market opens, our results are not only explanatory but also predictive. We find that a one percent positive standardized surprise about the state of the economy in the announcement will decrease the stock market return by 0.057%. This result is robust even when we estimate an EGARCH specification or include control variables such as the dividend yield, the risk-free rate and a dummy for announcement days in the mean equation. We also find that the reaction of the stock market to unanticipated news in advance GDP announcements is asymmetric. On the other hand, we find that the uncertainty resolved on announcement days has a significant negative effect on the conditional volatility. Although in the presence of control variables, this effect is less significant, it is robust across different measures. The higher the degree of uncertainty resolved on the announcement day, the smaller the conditional volatility of returns will become on announcement days. This result suggests that the conditional volatility on an announcement day when a higher level of uncertainty is resolved is smaller than the conditional volatility on another announcement day when a relatively lower level of uncertainty is resolved. One should note that the conditional volatility of returns might still be higher than the conditional volatility on non-announcement days. Our simulation results suggest that our model is capable of replicating these empirical results for a range of risk aversion parameters. Furthermore, in line with the existing literature, we find that the effect of unanticipated news lasts less than a day. In other words, the information in the announcement is incorporated quickly into the price. Following Campbell (1991), we decompose returns into three components and find that the change in expectations about future growth due to unanticipated news is the main source of this observed reaction. Finally, we analyze the reaction of the stock market returns to employment situation announcements and find the implications of our model hold for news that are less than perfectly correlated with the growth rate.

The rest of the paper is organized as follows: Section 2 introduces the setup and assumptions of the general model and presents analytical solutions for asset prices in this framework. Section 3 discusses the intuition behind our model in a simplified framework and presents the implications of our model. Section 4 discusses the data employed in our empirical analysis. Section 5 summarizes our empirical approach to test the implications of our model. Section 6 presents the empirical results on the effect of advance GDP announcement news on the stock market, risk-free rate and excess return dynamics. Section 7 analyzes the sources of the stock market's reaction to news. Section 8 summarizes the empirical results on the effect of employment news on the stock market returns. Section 9 concludes. All proofs are in the appendix.

2 The Model

In this section, we develop a dynamic general equilibrium asset pricing model where investors learn about the growth rate of the economy by observing dividend realizations between public announcements.

Consider a discrete time standard pure exchange economy (Lucas (1978)) with a representative investor whose preferences can be represented by a constant relative risk aversion utility function,

$$U(C_t) = \begin{cases} \frac{C_t^{1-\gamma}}{1-\gamma} & \text{if } \gamma \neq 1 \\ \log(C_t) & \text{if } \gamma = 1 \end{cases} \tag{1}$$

where C_t denotes the investor's consumption in period t and γ is the coefficient of relative risk aversion. The investor's opportunity set comprises a risky asset, whose dividend at time t is denoted by D_t and a riskless asset whose risk-free rate of return is r_t^f. We assume that the supply of the risky asset is fixed and normalized to 1. Let d_t denote the log-dividend process, i.e. $d_t = \log(D_t)$. We further assume that dividends grow according to the following process:

$$\Delta d_t = \mu_{z_n} + \sigma_{z_n}\varepsilon_t \quad \text{for } T_{n-1} < t \leq T_n \tag{2}$$

where Δ denotes the first difference operator (i.e. $\Delta d_t = d_t - d_{t-1}$), ε_t is an iid Gaussian random variable (i.e. $\varepsilon_t \sim N(0,1)$) and T_n is the release time of the n^{th} announcement that reveals what the growth rate of the economy has been since the release of the previous announcement at time T_{n-1}. We assume that announcements are regularly scheduled. Let T denote the number of periods between announcements, i.e. $T = T_n - T_{n-1}$ for $n = 1, 2, \ldots$. z_n is the state of the economy between announcement days T_{n-1} and T_n. Although z_n is realized on the previous announcement day, T_{n-1}, we assume that investors do not observe the current growth rate of the dividend stream until the n^{th} announcement day, T_n. In other words, let $\mathcal{F}_t$ denote the investor's information set at time t which consists of past announcements and past dividend realizations, then z_n is observed on the n[th] announcement day (i.e. $z_n \in \mathcal{F}_{T_n}$).

For analytical tractability, we assume that the state variable takes N different values. Specifically, we assume that $z_n \in \{1, 2, \ldots, N\}$ and without loss of generality $\mu_1 > \mu_2 > \ldots > \mu_N$. We assume that the state variable possibly takes a new value only on announcement days, hence we use the time index n to track the state variable rather than the time index t that tracks the dividend process. We do not restrict the variance of the growth rate of different states in the general framework, whereas the variances are set equal in the simplified framework. We further assume that the state variable evolves according to a first-order N-state Markov chain where the transition probabilities are given by

$$\{\Pr(z_n = i | z_{n-1} = j)\} = \{q_{ji}\} = \mathbf{Q} \tag{3}$$

where $\mathbf{Q}$ is an $N \times N$ matrix of transition probabilities. The intuition behind this specification is simple. The dividends are paid out every period, whereas the dividend growth possibly switches to a different state every T periods on announcement days[5]. On the announcement day, the news reveals what the true growth rate has been since the previous announcement. The main advantage of this specification is that not only is it analytically tractable but it is also realistic. In the real world, investors do not observe the growth rate of the economy in the current quarter until the Bureau of Economic Analysis (BEA) releases advance GDP estimates in the following quarter. Although investors do not observe the current growth rate between announcements, they learn about the growth rate by observing dividend realizations in the interim. On the announcement day, investors form their beliefs about the state of the economy until the next announcement depending on the current announcement. In other words, the announcement not only reveals the state of the economy in the last quarter but also affects investors' beliefs about the state of the economy until the next announcement.

Our model is a general equilibrium model with a representative investor learning about the dividend process. First of all, we analyze a general equilibrium framework to simplify the analysis and focus on one type of news, namely the cash flow news. One can think of extending this framework to a partial equilibrium. However, it complicates the analysis without a substantial gain in intuition about the question addressed by this paper. Secondly, instead of a market microstructure structure, we develop a model without strategic interaction and trading. Recently, Reny and Perry (2005) show the strategic foundation for rational expectations equilibrium by considering a double auction with large number of buyers and sellers. This large double auction equilibrium is almost efficient, almost fully aggregates investors information sets and is arbitrarily close to the unique fully revealing rational expectations equilibrium. Hence, our model can be considered as a reduced form model of a market microstructure model where the number of buyers and sellers is large. Finally, our model is a learning model rather than a model where investors know the true growth rate of the dividend process. A learning model is a natural choice for the question addressed by this paper. Furthermore, asset pricing models with learning are known to generate dynamics such as time-varying volatility and expected returns that standard Lucas asset pricing models fail to do. Learning is not the only way to generate such dynamics in asset returns, but it is relatively easy to quantify in this framework.

Our model is closest to that of Veronesi (2000). In his paper, he analyzes how information quality affects stock returns. He develops a dynamic general equilibrium Lucas-type asset pricing model where investors learn about the growth rate of the economy through dividend realizations and an external signal. Our model differs from his

[5] One can think our model as a model with daily dividend realizations and quarterly regimes.

in terms of the information flow of the external signal. Instead of modeling the external signal as a continuous process, it is modeled as a discrete periodic process since the question we address is different from his. Furthermore, in contrast to Veronesi (2000), we assume that the external signal is not noisy. In other words, the external signal reveals the growth rate of the economy. Our model would nest his if we assume that the announcement is a noisy signal about the growth rate of the economy. Our model is also close to the framework of Cecchetti, Lam, and Mark (1990) where they analyze serial correlation of returns with a Lucas asset pricing model similar to ours. Our model differs from theirs in terms of the signal extraction problem that investors face. In their model, investors know the true state of the economy. That is, there is no learning in their model[6]. However, we assume that investors learn about the state of the economy by observing dividend realizations and public announcements.

2.1 Investors' Belief

Before proceeding to the analytical derivation of equilibrium asset prices and returns, we need to analyze how investors' beliefs about the growth rate evolve over time. Investors form their beliefs about the growth rate of the economy by observing dividend realizations and announcements[7]. For $T_{n-1} \leq t \leq T_n$ and $n = 1, 2, \ldots,$ let π_{it} denote investors' posterior beliefs that the current state of the economy is i given their information set at time t. Mathematically, $\pi_{it} = \Pr(z_n = i|\mathcal{F}_t) = \Pr((\mu_{z_n}, \sigma_{z_n}) = (\mu_i, \sigma_i)|\mathcal{F}_t)$ for $i = 1, 2, \ldots, N$. Furthermore, let π_{i0} denote the initial prior probability at time 0 before observing any announcements or dividend realizations. The following lemma characterizes the law of motion of π_{it}:

Lemma 1. *Investors' posterior beliefs about the state of the economy evolves as follows:*

$$\pi_{it} = \begin{cases} \sum_{j=1}^{N} q_{ji} 1_{\{z_{n-1}=j\}} & \textit{if } t = T_{n-1} \\ \frac{\phi(\frac{\Delta d_t - \mu_i}{\sigma_i})\pi_{i,t-1}}{\sum_{j=1}^{N} \phi(\frac{\Delta d_t - \mu_j}{\sigma_j})\pi_{j,t-1}} & \textit{if } T_{n-1} < t < T_n \\ 1_{\{z_n=i\}} & \textit{if } t = T_n \end{cases} \tag{4}$$

for $n = 1, 2, \ldots$ *where* $\phi(\cdot)$ *is the standard normal density function.*

Proof. All proofs are in the appendix. □

Before proceeding to the intuition of the signal extraction, one should note that the announcement reveals not only the true growth rate of the economy since the previous announcement but also reveals information about the future growth rate. In other words, there are two different probabilities on announcement days. The first one is the probability of the currently released announcement that is given by the third case in Equation (4). The second one is the prior probability about the next announcement that is given by the second case in Equation (4).

The intuition of the signal extraction described in the above lemma is simple. Before observing any signals (dividend realizations) about the current growth rate, having observed the last announcement, investors form prior beliefs about the next state according to the law of motion of the state variable. As they start observing signals about

[6]One can obtain their model by assuming that announcements occur every period in our model, i.e by setting $T = 1$.

[7]Observing equilibrium prices does not reveal any further information about the growth rate, since we assume that investors have common information about the economy derived from past announcements and dividend realizations.

the current growth rate, they update their prior beliefs according to the Bayes' law. Therefore, their posterior beliefs about the current growth rate is a function of the last announcement and the dividend realizations since the previous announcement.

π_{it} characterizes not only investors' fluctuating expectations but also investors' uncertainty about the growth rate of the economy. As we discuss in the next section, it is the investors' fluctuating expectations that generates dynamics in prices and returns that is not possible with standard models. Fluctuation in beliefs about fundamentals is the main theoretical link between the stock market's reaction and announcements about fundamentals.

2.2 Equilibrium Asset Prices

We next solve for the equilibrium price and return of the risky asset. Equilibrium prices and interest rates are determined by standard market clearing conditions. Let P_t denote the price of the risky asset, then investors choose the fraction of wealth invested in the risky asset, α_t, and consumption, C_t, in order to solve the following maximization problem:

$$\max_{C_t,\alpha_t} E_t[\sum_{\tau=0}^{\infty} \beta^{\tau} U(C_{t+\tau})] \tag{5}$$

subject to the budget constraint:

$$W_{t+1} = \Big(W_t - C_t\Big)\left(\alpha_t\left(\frac{P_{t+1} + D_{t+1} - P_t}{P_t}\right) + (1-\alpha_t) r^f_{t+1}\right) \tag{6}$$

where W_t denotes investors' wealth at time t. β is the investor's time impatience parameter and $E_t[\cdot]$ denotes expectation conditional on the available information at time t, $\mathcal{F}_t$. The Euler equation for the maximization problem is given by

$$P_t = \beta E_t\left[\frac{U'(C_{t+1})}{U'(C_t)}(P_{t+1} + D_{t+1})\right] \tag{7}$$

An equilibrium is defined by a vector process $(C_t, \alpha_t, P_t, r^f_t)$ such that the Euler equation in (7) holds and markets clear, i.e. $\alpha_t = 1$ and $C_t = D_t$.

Before proceeding to the derivation of the price of the risky asset on non-announcement days, the following lemma characterizes the price of the risky asset on announcement days. We assume that the transversality condition holds so that there is a unique equilibrium[8].

Lemma 2. *The equilibrium price of the risky asset on announcement days is given by*

$$P_{T_n} = \lambda_{z_n} D_{T_n} \quad \textit{for } n = 1, 2, \ldots$$

λ_{z_n} *can take* N *different values depending on the announcement where* $\boldsymbol{\lambda} = (\lambda_1, \ldots, \lambda_N)'$ *is given by :*

$$\boldsymbol{\lambda} = (\mathbf{I} - \mathbf{HQ})^{-1}\mathbf{QG} \tag{8}$$

where $\mathbf{Q}$ *is the transition probability matrix defined in Equation (3).* $\mathbf{G}$ *is a* $N \times 1$ *vector whose* i^{th} *element,* g_i*, is given by* $g_i = \frac{(\beta e^{a_i})^{T+1}-1}{\beta e^{a_i}-1} - 1$. $\mathbf{H}$ *is a* $N \times N$ *diagonal matrix whose* i^{th} *diagonal element,* h_i*, is given by* $h_i = (\beta e^{a_i})^T$. a_i *is a constant that depend on model parameters and is given by* $a_i = (1-\gamma)\mu_i + (1-\gamma)^2\sigma_i^2/2$.

[8] The transversality condition for our model can be expressed as $\lim_{\tau\to\infty} E_t\left[\beta^{\tau}\left(\frac{D_{t+\tau}}{D_t}\right)^{-\gamma} P_{t+\tau}\right] = 0$. A necessary and sufficient condition for the transversality condition to hold is $\beta e^{a_i} < 1$ for $i = 1, 2, \ldots, N$ where a^i is defined in Lemma 2.

Proof. All proofs are in the appendix. □

The price-dividend ratio switches between N possible values on announcement days. The lemma suggests that the price-dividend ratio between announcement days is a weighted average of the N possible values. The price of the risky asset on announcement days is similar to the one derived in Cecchetti, Lam, and Mark (1990). One can obtain their derivation of the price of the risky asset by setting $T = 1$. The following proposition solves for the equilibrium price of the risky asset between announcement days.

Proposition 1. *The price of the risky asset at time t ($T_{n-1} < t < T_n$) can be expressed as:*

$$P_t = \sum_{i=1}^{N} \left[\left(\frac{(\beta e^{a_i})^{T_n - t + 1} - 1}{\beta e^{a_i} - 1} - 1 \right) \pi_{it} + (\beta e^{a_i})^{T_n - t} \lambda_i \pi_{it} \right] D_t \tag{9}$$

where λ_i and a_i are constants defined in Lemma 2.

Proof. All proofs are in the appendix. □

The price and the return processes are functions of the horizon to the announcement day and investors' beliefs about the current state of the economy. Furthermore, π_{it} not only depends on dividend realizations but also reflects the previous announcement, hence the price is a function of both the previous announcement and the current state of the economy which is revealed on the next announcement day. Although this model is both analytically tractable and realistic, like any other model, it has its shortcomings. The main disadvantage is its implications for the price-dividend ratio. The price-dividend ratio is time-varying between announcement days, but it reverts to one of the N values, $(\lambda_1, \lambda_2 \ldots, \lambda_N)$, on announcement days. However, one should note that any model with regime switching in the fundamentals is subject to the same criticism. The following corollary characterizes the law of motion for the return, the main interest of this paper.

Corollary 1. *Let r_t denote the return process for the risky asset. Then r_t can be expressed as:*

$$\begin{aligned} r_t =& \frac{P_t + D_t - P_{t-1}}{P_{t-1}} \\ =& \frac{\sum_{i=1}^{N} \left(\frac{(\beta e^{a_i})^{T_n - t + 1} - 1}{\beta e^{a_i} - 1} - 1 \right) \pi_{it} + (\beta e^{a_i})^{T_n - t} \lambda_i \pi_{it}}{\sum_{i=1}^{N} \left(\frac{(\beta e^{a_i})^{T_n - t + 2} - 1}{\beta e^{a_i} - 1} - 1 \right) \pi_{i,t-1} + (\beta e^{a_i})^{T_n - t + 1} \lambda_i \pi_{i,t-1}} \cdot e^{\mu_{z_n} + \sigma_{z_n} \varepsilon_t} - 1 \end{aligned} \tag{10}$$

Proof. All proofs are in the appendix. □

Notice that the return process depends on investors's beliefs not only in the current period but also in the last period. In our model, one can consider dividend shocks (ε_t) as unscheduled announcements or news. The main difference between announcement day returns and non-announcement day returns is the presence of a covariance term between dividend shocks and investors' beliefs. In other words, by construction, the dividend shock on announcement days is not correlated with the announcement conditional on investors' information set before the announcement day. However, on non-announcement days, the dividend shock has an additional effect on stock returns through the updating process of investors' beliefs. In a simplified version of the model described in the next section, we derive analytical expressions for both mean return and volatility of returns on announcement days and discuss the intuition behind our results.

3 A Simple Model

In this section, we present a simplified version of the model introduced above. The simplified version of the model is an extreme case of our model where all uncertainty is resolved on the announcement day.

We assume that the dividends grow according to Equation (2). There is only one announcement about the growth rate of the dividend process, which reveals the true growth rate. Specifically,

$$\Delta d_t = \mu_{z_{T^*}} + \sigma\varepsilon_t \tag{11}$$

where $z_{T^*} \in \{1,2\}$ is similar to the news variable discussed in the previous section. The state of the economy is realized at time 0. However, it is not observed until the announcement day, T^*, i.e. $z_{T^*} \in \mathcal{F}_{T^*}$. Before the announcement day, T^*, the investors do not observe the true growth rate, however, they face a signal extraction problem. They learn about the true growth rate by observing dividend realizations. We further assume that there are two states of the economy, high growth ($z_{T^*} = 1$) and low growth ($z_{T^*} = 2$) state. In other words, the growth rate of the economy in state 1 is greater than the growth rate in state 2, i.e. $\mu_1 > \mu_2$[9]. This model can be obtained as a special case of the general model discussed above by setting $N = 2$ and $q_{11} = q_{22} = 1$[10]. That is, once the news variable is announced on the first announcement day, it takes the same value at every future announcement day with probability 1. Hence, it reveals the true future growth rate of the economy.

The learning process and price-dividend ratio are similar to the general model. Let π_0 denote the prior probability of high growth state before observing any announcements or dividend realizations. Let π_t denote $\Pr(z_{T^*} = 1|\mathcal{F}_t)$ (or equivalently, $\Pr(\mu_{z_{T^*}} = \mu_1|\mathcal{F}_t)$), then

$$\pi_t = \begin{cases} \frac{\phi(\frac{\Delta d_t - \mu_1}{\sigma})\pi_{t-1}}{\phi(\frac{\Delta d_t - \mu_1}{\sigma})\pi_{t-1} + \phi(\frac{\Delta d_t - \mu_2}{\sigma})(1-\pi_{t-1})} & \text{for } t < T^* \\ 1_{\{z_{T^*}=1\}} & \text{for } t \geq T^* \end{cases} \tag{12}$$

where $\phi(\cdot)$ is the standard normal density function and $1_{\{\cdot\}}$ is an indicator function. The price-dividend ratio of the risky asset is given by

$$\frac{P_t}{D_t} = k_1\pi_t + k_2(1-\pi_t) \tag{13}$$

where $k_{z_{T^*}} = (\beta e^{a_{z_{T^*}}})/(1-\beta e^{a_{z_{T^*}}})$ and $a_{z_{T^*}}$ are constants defined in Lemma 2.

The price-dividend ratio is a function of investors' posterior beliefs until the announcement day when uncertainty about the growth rate is completely resolved. Although the price-dividend ratio is time-varying before the announcement day, it is constant afterwards. This is a special case of the general model where uncertainty is never completely resolved, even in the limit. Although the simple model is a special case,

[9] For simplicity, we assume that variances of the dividend growth process in different state are identical, i.e. $\sigma_1 = \sigma_2 = \sigma$. However, in our empirical analysis, we estimate a Hamilton (1989) model for real-time GDP with regime switching both in mean and variance.

[10] One should note that setting $q_{11} = q_{22} = 1$ implies $q_{12} = q_{21} = 0$

it provides intuition about return dynamics on the announcement day relative to non-announcement days. The following proposition derives closed-form solutions for expected return and conditional volatility on the announcement day.

Proposition 2. *Let r_{T^*} denote the return on the announcement day T^*, then*

$$r_{T^*} = \frac{(k_1 1_{\{z_{T^*}=1\}} + k_2 1_{\{z_{T^*}=2\}} + 1)e^{\mu_{z_{T^*}} + \sigma\varepsilon_{T^*}}}{k_1\pi_{T^*-1} + k_2(1-\pi_{T^*-1})} - 1 \tag{14}$$

The expected return and the conditional volatility on the announcement day are given by, respectively,

$$E_{T^*-1}[r_{T^*}] = \frac{(k_1+1)e^{\mu_1+\sigma^2/2}\pi_{T^*-1} + (k_2+1)e^{\mu_2+\sigma^2/2}(1-\pi_{T^*-1})}{k_1\pi_{T^*-1} + k_2(1-\pi_{T^*-1})} - 1 \tag{15}$$

$$\begin{aligned} var_{T^*-1}[r_{T^*}] = & \frac{(k_1+1)^2 e^{2\mu_1+2\sigma^2}\pi_{T^*-1} + (k_2+1)^2 e^{2\mu_2+2\sigma^2}(1-\pi_{T^*-1})}{(k_1\pi_{T^*-1} + k_2(1-\pi_{T^*-1}))^2} \\ & - \frac{((k_1+1)e^{\mu_1+\sigma^2/2}\pi_{T^*-1} + (k_2+1)e^{\mu_2+\sigma^2/2}(1-\pi_{T^*-1}))^2}{(k_1\pi_{T^*-1} + k_2(1-\pi_{T^*-1}))^2} \end{aligned} \tag{16}$$

Proof. All proofs are in the appendix. □

Notice that both the expected value and conditional volatility of equilibrium stock returns are functions of investors' beliefs. Although this model is simple, it generates time-varying dynamics both in the expected value and the conditional volatility of returns. Furthermore, since π_t is autocorrelated, this model might be able to account for GARCH-type behavior of conditional volatility, which is a function of π_t. One should note that the standard Lucas-type model with no learning implies constant expected returns and conditional volatility and cannot account for empirical facts observed in the data. Before proceeding to summarizing the main implications of the simplified model for the mean return, a definition of the unanticipated news (or equivalently, surprise) is in order:

Definition 1. *Let u_{T^*} denote the unanticipated news on the announcement day. u_{T^*} is defined as follows:*

$$u_{T^*} = (1-\pi_{T^*-1})1_{\{z_{T^*}=1\}} + \pi_{T^*-1}1_{\{z_{T^*}=2\}} \tag{17}$$

where first term on the right-hand side is the unanticipated good news whereas the second term is the unanticipated bad news.

The definition of the surprise is quite intuitive. If the announcement reveals good news in the sense that the economy is in the high growth state, i.e. $z_{T^*} = 1$, then π_{T^*-1} is the anticipated (or expected) part of the announcement given investors' information set at time $T^* - 1$. The unanticipated part of the announcement is the difference between the true value of the announcement and the anticipated part. Similarly, for bad news, the anticipated part is $1 - \pi_{T^*-1}$ and the unanticipated part is π_{T^*-1}.

Proposition 3 (Implications for the mean return on the announcement day)**.** *Assuming that the announcement is released on the announcement day before the stock market opens, then*

1. *Announcement-day return is a function of the unanticipated news. Specifically,*

$$r_{T^*} = \begin{cases} \frac{(k_1+1)e^{\mu_1+\sigma\varepsilon_{T^*}}}{k_1+(k_2-k_1)u_{T^*}} - 1 & \text{if } z_{T^*} = 1 \\ \frac{(k_2+1)e^{\mu_2+\sigma\varepsilon_{T^*}}}{k_2+(k_1-k_2)u_{T^*}} - 1 & \text{if } z_{T^*} = 2 \end{cases} \tag{18}$$

2. *If investors are more risk averse than a log utility investor, i.e $\gamma > 1$, then unanticipated positive news (negative) news about the state of the economy decreases (increases) the mean return on announcement days. In other words, in the case of positive (negative) news, the mean return is negatively (positively) correlated with the size of the surprise. On the other hand, unanticipated positive (negative) news is good (bad) for the mean announcement-day return if $\gamma < 1$. Finally, the unanticipated news has no effect on the mean return on announcement days if investors have log utility.*

3. *The effect of unanticipated news is asymmetric. In other words, the effect of a positive unanticipated news is different from that of a negative one. Specifically, if $(k_1+1)e^{\mu_1} > (k_2+1)e^{\mu_2}$, then the absolute effect of a positive unanticipated news on the mean stock return is greater than that of a negative unanticipated news of the same magnitude.*

Proof. All proofs are in the appendix. □

The first implication of our model is in line with the existing literature, which states that returns react to the unanticipated component of news on announcement days. The intuition is simple. Investors' beliefs about the announcement already includes the anticipated component of the announcement. Hence, the price already reflects the anticipated part of the announcement. On the announcement day, additional information which has not been incorporated into investors' beliefs is revealed, investors update their expectation about the future growth rate. Hence, the mean return reacts according to the change in investors' beliefs due to additional information in the announcement.

The intuition from a two-period model applies to the second implication. In a two-period model with a representative investor whose preferences are represented by a power utility, an unanticipated higher growth rate has two effects in equilibrium. The first effect is the income effect. An unanticipated good news about the growth rate results in a higher endowment in the second period. Investors are willing to pay more for the risky asset which is a claim on the second period consumption since the payoff is higher than previously expected. Hence, the income effect increases the current equilibrium price of the risky asset. The second effect is the substitution effect. Investors are willing to consume more in the current period due to a higher than expected consumption in the second period. In a power utility framework, a higher endowment in the second period increases the stochastic discount factor. Therefore, investors are discounting future payoffs at a higher rate. Hence, the substitution effect decreases the current equilibrium price of the risky asset. Which effect dominates in equilibrium depends on investors' risk aversion parameter, γ. If investors are more risk averse than a log-utility investor, i.e. $\gamma > 1$, the substitution effect dominates the income effect and the equilibrium asset price decreases. Hence, unanticipated positive news has a negative effect on returns on announcement days. The opposite holds when $\gamma < 1$. If investors have a log utility (i.e. $\gamma = 1$), income and substitution effects cancel out, hence the news does not have any effect on returns.

Among other factors such as investors' time impatience parameter, β, and risk aversion parameter, γ, the effect of surprises on returns depends on the difference between growth rates, μ_1 and μ_2. As the difference between the growth rates gets larger, the coefficient of u_{T^*} will increase.

The second implication might give theoretical support for the recent empirical findings that returns react negatively to positive surprises. Boyd, Hu, and Jagannathan (2005) find that positive unemployment surprises have a negative effect on returns.

One should be careful interpreting the second implication. Our claim is about the unanticipated part of news, not the total effect of the announcement. The third implication is about the overall effect of the announcement. If the inequality in the third implication holds, then the mean return on an announcement day with positive news is higher than the mean return on another announcement day with negative news. In other words, the effect of the unanticipated news depends on the state of the economy revealed on the announcement day. Hence, the effect of unanticipated news is asymmetric and depends on whether it is good news or bad news. If $(k_1+1)e^{\mu_1} > (k_2+1)e^{\mu_2}$, then the absolute effect of a positive unanticipated news on the mean stock returns is greater than that of a negative unanticipated news of the same magnitude.

Before proceeding to the implications of the model for conditional volatility of returns on the announcement day, we first define the uncertainty about the announcement.

Definition 2. *Let ω_t denote the uncertainty about the announcement given investors' information set at time t. Then we define ω_t as follows:*

$$\omega_t = \pi_t(1-\pi_t). \tag{19}$$

Our definition of uncertainty is intuitive. ω_t is a quadratic concave function of investors' posterior beliefs about the state of the economy, π_t, and is maximized when π_t is equal to 0.5, when investors are most uncertain about the growth rate. It is zero when investors are certain about the growth rate, i.e. $\pi_t = 0, 1$. Furthermore, the measure of uncertainty is independent of the announced value of the news variable.

Proposition 4 (Implications for conditional volatility of returns on the announcement day)**.** *Conditional volatility of returns on announcement days is a nonlinear function of not only investors belief about the true growth rate of the economy but also uncertainty about the announcement. Specifically,*

$$var_{T^*-1}[r_{T^*}] = \frac{m_2^2(e^{\sigma^2}-1) + (m_1^2 - m_2^2)(e^{\sigma^2}-1)\pi_{T^*-1} + (m_1-m_2)^2\omega_{T^*-1}}{k_2^2 + (k_1^2-k_2^2)\pi_{T^*-1} - (k_1-k_2)^2\omega_{T^*-1}} \tag{20}$$

where $m_{z_{T^*}} = (k_{z_{T^*}}+1)e^{\mu_{z_{T^*}}+\sigma^2/2}$.

Proof. All proofs are in the appendix. □

Although the effect of unanticipated news on announcement day returns is easy to characterize, the effect of uncertainty is somewhat ambiguous and depends on the model parameters. However, one would expect conditional volatility on announcement days to be a decreasing function of investors' uncertainty about the state of the economy prior to the announcement. Veronesi (1999) shows that the conditional volatility of returns is related to investors' uncertainty about the state of the economy and higher uncertainty leads to higher price sensitivity of the risky asset, hence to higher conditional volatility of returns. The higher conditional volatility is due to investors' willingness to hedge against their own uncertainty. In our model, the announcement reveals the true state of the economy and hence the uncertainty about the state of the economy is completely resolved on the announcement day. The higher the investors' prior uncertainty about the state of the economy, the smaller will be the conditional volatility of returns on the announcement day. One should note that the conditional volatility on non-announcement days is a increasing function of investors' uncertainty. The difference between announcement and non-announcement days is the resolution of uncertainty on announcement days. Our claim in this paper is that the resolution of investors' prior uncertainty about the state of the economy is the main reason for the observed behavior of conditional volatility on announcement days. As discussed in the empirical part of the paper, our model is capable of generating similar effects of uncertainty on conditional volatility to those observed in the data. However, our simulation results suggest that the effect of uncertainty on announcement day returns is sensitive to the risk aversion parameter γ.

One should note that the return on non-announcement days is also a function of investors' beliefs. As mentioned before, the dividend realizations between announcements can be considered as unscheduled news events. Return dynamics on non-announcement days react to these unscheduled news. Dividend realizations affect return dynamics through three channels. The mean return on non-announcement days react to unanticipated news in dividend realizations. However, differently from announcement-day returns, the dividend realization has an additional effect on returns on non-announcement days through its effect on investors' beliefs. Furthermore, the conditional moments of returns are affected by the covariance between dividend shocks and investors' beliefs. In our framework, the main difference between the return dynamics on announcement days and non-announcement days is the resolution of uncertainty on announcement days. On announcement days, investors do not update their beliefs about the state of the economy. Hence, the dividend shock affects returns on announcement days only through the first channel. It is the resolution uncertainty on announcement days why return dynamics on announcement days are different than those on non-announcement days. The reaction of conditional volatility depends on the degree of uncertainty resolved on the announcement day. In the next section, we describe the data set employed to quantify empirical measures of surprise and uncertainty.

4 Data

In this section, we describe the data set used in the empirical analysis. To quantify the model-based measures of surprise and uncertainty, we use real-time nominal GDP between quarterly vintages of 1970Q1 and 2004Q4. This data is available from the Federal Reserve Bank of Philadelphia. Quantifying the survey-based measures requires using nominal GDP forecasts of individual forecasters in addition to the real-time GDP data. We obtain individual forecasts from the Survey of Professional Forecasters data set that is also available from the Federal Reserve Bank of Philadelphia. The mean and standard deviation of individual forecasts are constructed using data between 1970Q1 and 2004Q4.

Estimating the empirical model requires daily stock returns, the date and the value of the announcement. We use daily (close-to-close) returns on the equal-weighted portfolio of all stocks in the Center for Research in Security Prices (CRSP) universe, from Jan/2/1970 to Dec/31/2004. The GDP announcement days are available from the Bureau of Economic Analysis (BEA) between 1970 and 2004. Since 1977, in a given quarter, BEA releases three estimates of GDP for the previous quarter, advance, preliminary and final estimates. Advance estimates, released towards the end of the first month in a given quarter, are the first official estimates of GDP in the previous quarter. Two subsequent releases, released towards the end of the second and third months of a quarter, are merely revisions to advance estimates. Between 1983 and 1985, the initial estimates of GDP (called flash estimates) were made available in the same quarter. Figure 1 presents the time line of events and release dates for GDP estimates in the third quarter of 2003 as an example.

[FIGURE 1 ABOUT HERE]

In this paper, we analyze the reaction of the stock market to advance GDP announcements since the other releases in a given quarter are revisions to the advance estimates and the flash estimates are only partially available. Therefore, we have only one announcement per quarter released towards the end of the first month of that quarter. The releases are generally announced at 8:30AM before the opening of the stock market. Hence, daily data frequency is adequate for this analysis. Furthermore, the release dates are publicly known in advance. The availability of historical release dates from BEA restricts our empirical analysis between 1970 and 2004.

Proxies for the daily risk-free rate and the daily dividend yield are used as control variables to check robustness of the empirical results to different specifications. The secondary market rate of 3-month US Government Treasury Bills, a proxy for the risk-free rate, is available from the Federal Reserve's H.15 release of daily interest rates. Return on income on equal-weighted portfolio of the NYSE-AMEX-NASDAQ market index, a proxy for dividend yield, is obtained from CRSP database.

5 Empirical Specification

In order to test the implications of our model, we need proxies for both investors' beliefs and uncertainty about the announcement. In this section, we develop two model-based and two survey-based measures of surprise and uncertainty. One should note that these measures are constructed using real-time data about the growth rate of the economy that could have been available to investors on the announcement day. As we discuss below, these measures are proxies for investors' beliefs and uncertainty one day before the announcement and are somewhat crude.

5.1 Model-Based Measures

Model-based measures, as the name suggests, are developed using the theoretical model for dividends in Equation (2). In order to construct the model-based measures, we need to form proxies of investors' beliefs about the state of the economy. Hence, we need to first estimate the model in Equation (2) using real-time nominal GDP growth rate.

For every announcement day T_n, a regime-switching model of Hamilton (1989) with two states is estimated using expanding window of data sets. The estimated regime-switching model can be expressed as:

$$\Delta \log(GDP_\tau) = gdp_\tau = \mu_{z_\tau} + \sigma_{z_\tau}\nu_\tau \tag{21}$$

where GDP_τ is the level of nominal GDP in quarter τ, $z_\tau = 1, 2$ is the state of the economy in quarter τ and ν_τ is a standard normal random variable. The log-likelihood of the estimation problem is:

$$\begin{aligned}\mathcal{L} \;=\;& \sum_{\tau=1}^{n} \log\Bigg[\frac{1}{\sqrt{2\pi\sigma_1^2}}\exp\bigg(-\frac{(gdp_\tau-\mu_1)^2}{2\sigma_1^2}\bigg)\Pr(S_\tau=1|\mathcal{F}_{\tau-1}) \\ &+ \frac{1}{\sqrt{2\pi\sigma_2^2}}\exp\bigg(-\frac{(gdp_\tau-\mu_2)^2}{2\sigma_2^2}\bigg)(1-\Pr(S_\tau=1|\mathcal{F}_{\tau-1}))\Bigg]\end{aligned} \tag{22}$$

The optimal inference and forecast about the state of the economy for each quarter can be found by iterating on the following pair of equations:

$$\Pr(S_\tau = 1|\mathcal{F}_\tau) = \frac{\phi(\frac{gdp_\tau - \mu_1}{\sigma_1})\Pr(S_\tau = 1|\mathcal{F}_{\tau-1})}{\sum_{i=1}^{2}\phi(\frac{gdp_\tau - \mu_i}{\sigma_i})\Pr(S_\tau = i|\mathcal{F}_{\tau-1})} \tag{23}$$

$$\Pr(S_{\tau+1} = 1|\mathcal{F}_\tau) = q_{11}\Pr(S_\tau = 1|\mathcal{F}_\tau) + (1 - q_{22})(1 - \Pr(S_\tau = 1|\mathcal{F}_\tau)) \tag{24}$$

where q_{11} and q_{22} are the diagonal elements of the transition probability matrix of z_τ. The model parameters are estimated by maximum likelihood estimation.

For every announcement day, T_n, the two-state regime-switching model is first estimated using quarterly real-time data up to but excluding the announcement to obtain investors' beliefs before the announcement, i.e. using revised estimates of GDP up to and including the $n-1^{\text{th}}$ quarter. Investors' beliefs about the current state of the economy are formed using estimated model parameters and Equation (23). Let $\hat{\pi}_{n|n-1}$ denote the forecast of the probability of the high growth state in the upcoming quarter that can be obtained from Equation (24). $\hat{\pi}_{n|n-1}$ is the investors' expectation about the future state of the economy in the following quarter. We next estimate the regime-switching model using quarterly real-time data up to and including the announcement on T_n that reveals the growth rate of the economy in the n^{th} quarter. We denote investors' beliefs about the state of the economy after the announcement by $\hat{\pi}_{n|n}$. $\hat{\pi}_{n|n}$ is the probability of high growth state given all available information including the announcement. One can think of our approach as an expanding window estimation approach for real-time GDP growth rate. Figure 1 exemplifies our estimation approach for the third quarter of 2003.

One should note that $\hat{\pi}_{n|n-1}$ is not investors' beliefs one period before the announcement but rather it is a proxy estimated using the latest data available to investors. By using real-time data, we employ the most recent data available to investors before and on the announcement day. Real-time data does not only include announcements but also the revisions to the announcements, an additional source of information about the growth rate between announcements. Hence, when forming beliefs, investors also make use of the information flow between announcement days.

Having obtained a proxy for investors' belief about the growth rate of the economy, the first model-based measures of surprise and uncertainty are derived from the corresponding theoretical measures defined in Equations (17) and (19), respectively. Specifically, we define a proxy for the surprise in the announcement as the percentage change in investors' beliefs due to the announcement[11], i.e. $\hat{u}_{T_n} \equiv (\hat{\pi}_{n|n} - \hat{\pi}_{n|n-1})/\hat{\pi}_{n|n}$. Similarly, the uncertainty about the n^{th} announcement, $\hat{\omega}_{T_n}$, is defined as $\hat{\omega}_{T_n} = \hat{\pi}_{n|n-1}(1 - \hat{\pi}_{n|n-1})$. One should note that surprise in the n^{th} announcement is observable on the announcement day, T_n, whereas uncertainty is observed before the announcement.

The first model-based measures of surprise and uncertainty are defined, respectively, as the forecast error and the standard deviation of the forecast when forecasting the state of the economy. By-products of the above recursive estimation are time-varying growth rate estimates for both states of the economy on every announcement day. The investors do not only update their beliefs about the state but also the growth rate of the economy. We can easily extend the first model-based measures as the forecast error and standard deviation of the forecast when forecasting the growth rate rather than the state of the economy. Let $\hat{\mu}_{i,n-1}$ denote the estimated growth rate in state i

[11] Or equivalently, one can think of the first model-based measure as the percentage forecast error made when forecasting the state of the economy.

using real-time data up to and including revised estimates for quarter $n-1$, whereas $\hat{\mu}_{i,n}$ is the estimated growth rate in state i using real-time data including the advance announcement on T_n. The second model-based measures of surprise and uncertainty are defined as follows:

$$\hat{u}_{T_n} = \frac{\widehat{\overline{\mu}}_{n|n} - \widehat{\overline{\mu}}_{n|n-1}}{\overline{\mu}_{n|n}} \tag{25}$$

$$\hat{\omega}_{T_n} = (\hat{\mu}_{1,n-1} - \widehat{\overline{\mu}}_{n|n-1})^2 \hat{\pi}_{n|n-1} + (\hat{\mu}_{2,n-1} - \widehat{\overline{\mu}}_{n|n-1})^2 (1 - \hat{\pi}_{n|n-1}) \tag{26}$$

where $\widehat{\overline{\mu}}_{n|n-1} = \hat{\mu}_{1,n-1}\hat{\pi}_{n|n-1} + \hat{\mu}_{2,n-1}(1-\hat{\pi}_{n|n-1})$ and $\widehat{\overline{\mu}}_{n|n} = \hat{\mu}_{1,n}\hat{\pi}_{n|n} + \hat{\mu}_{2,n}(1-\hat{\pi}_{n|n})$.

5.2 Survey-Based Measures

Survey-based measures of surprise and uncertainty are constructed using the Survey of Professional Forecasters, described in detail in the data section. The survey-based measures are defined directly without using a proxy for investors' beliefs about the state of the economy.

The first measure is based on the level of nominal GDP. The measure of surprise is defined as the difference between the GDP announcement and the most recent mean forecast of nominal GDP. The measure of uncertainty is defined as the dispersion (disagreement) among forecasters. In particular, let for_{in} denote forecaster i's forecast of GDP in quarter n and GDP_n denote the real-time value of nominal GDP released on the announcement day T_n. Then the first survey-based measures of surprise and uncertainty in the GDP announcement for period t are defined as follows:

$$\hat{u}_{T_n} = \frac{GDP_n - \overline{for}_n}{GDP_n} \tag{27}$$

$$\hat{\omega}_{T_n} = \left(\frac{1}{m_n - 1}\sum_{i=1}^{m_n}(for_{in} - \overline{for}_n)^2\right)^{1/2} \tag{28}$$

where m_n is the number of forecasters in period n and $\overline{for}_n$ is the mean forecast.

The second measure is based on forecasts of the growth rate of GDP and defined in a similar fashion:

$$\hat{u}_{T_n} = \frac{gdp_n - \widetilde{for}_n}{gdp_n} \tag{29}$$

$$\hat{\omega}_{T_n} = \left(\frac{1}{m_n - 1}\sum_{i=1}^{m_n}(\log(for_{in}/for_{in-1}) - \widetilde{for}_n)^2\right)^{1/2} \tag{30}$$

where $\widetilde{for}_n$ is the mean growth rate forecast defined as $\widetilde{for}_n = \frac{1}{m_n}\sum_{i=1}^{m_n}\log(for_{in}/for_{in-1})$.

As before, both measures of surprise are observed on the announcement day and both uncertainty measures are observed before the announcement day.

In order to obtain a consistent measure of unanticipated news and uncertainty across different approaches, we standardize each measure by its standard deviation. Figures 2 and 3 present model-based and survey-based measures of surprise and uncertainty, respectively.

[FIGURES 2 and 3 ABOUT HERE]

Tables 1 and 2 summarize the correlation across different measures of unanticipated news and uncertainty, respectively.

[TABLES 1 and 2 ABOUT HERE]

One should note that there are several issues with both the model- and survey-based measures related to the time line of events. Figure 4 summarizes the construction time line of measures for third quarter of 2003 as an example.

[FIGURE 4 ABOUT HERE]

First of all, real-time data employed to obtain model-based measures uses all the available data before the announcement. It includes the final revision of the previous quarter's advance GDP estimates that is released in the last month of the current quarter. One caveat is that there is a one month gap between the release of the final revision to the previous quarter's GDP and the release of the advance estimate of the current quarter's GDP. The model-based measures are somewhat crude since investors might observe other informative variables and update their beliefs about the health of the economy between the final estimate and advance estimate release dates. For example, between final estimate and advance estimate release dates, investors might observe the unemployment figures that might reveal some information about the growth rate of the economy. Final estimates are the most recent data available about the GDP. Similar criticism is also relevant for the survey-based measures. Survey results are released in the middle of the quarter. Therefore, there is a 2.5 month gap between the survey release date and the announcement day. This criticism is more problematic for the uncertainty measures than for the surprise measures. The surprise measures are obtained using the release on the announcement day. On the other hand, the uncertainty measures are obtained using real-time and survey data, which are based on information 1 and 2.5 months before the announcement.

One should note that any study on the effect of public announcements would be subject to the same criticism. There would be a time gap between the announcement day and release date of any measure of surprise or uncertainty constructed using either macroeconomic or survey data.

5.3 Model Specification

Using these four different measures of surprise and uncertainty, we analyze the return dynamics on announcement days using a GARCH specification with unanticipated news in the return equation and uncertainty in the variance equation. In this strand of literature, it is quite common to fit a modified GARCH model with explanatory variables to daily returns and analyze the dynamics on and around announcement days. Following Flannery and Protopapadakis (2002), Bomfim (2003) and Li and Engle (1998), we first fit a simple GARCH(1,1) to daily stock returns with explanatory variables implied by our model. The empirical specification can be summarized by the following set of equations:

$$\begin{aligned} r_t &= \delta_0 + \delta_1 u_t + e_t && (31) \\ E_{t-1}[e_t] &= 0 \\ E_{t-1}[e_t^2] &= \upsilon_t^2 \\ \upsilon_t^2 &= \theta_0 + \theta_1 \omega_{t-1} + \theta_2 \omega_{t-1}^2 + \theta_3 \upsilon_{t-1}^2 + \theta_4 e_{t-1}^2 && (32) \end{aligned}$$

where $e_t \sim N(0, \upsilon_t^2)$. One should note that the conditional volatility is not a function of the surprise since the surprise is only observed on the announcement day.

The choice of a simple GARCH model is a natural one. First of all, one can think of the GARCH specification as a first approximation to the conditional volatility implied by our model, rather than a non-parametric volatility model. This fact relatively simplifies the empirical analysis. More importantly, a GARCH specification lets us compare the empirical results in this paper to those in the existing literature.

The implications of our theoretical model for the coefficients of the empirical specification can be summarized as follows: Our model implies that a positive unanticipated news decreases the mean return on announcement days. In other words, the coefficient of unanticipated news, u_t, in the empirical specification should be negative and significant, i.e. $\delta_1 < 0$. On the other hand, we expect the resolution investors' prior uncertainty about the announcement to decrease the conditional volatility of returns on announcement days. Therefore, the coefficient of uncertainty, ω_{t-1} should be negative, i.e. $\theta_1 < 0$. On the other hand, the magnitudes of these parameters depend on the risk aversion parameter, the time impatience parameters and the difference between the growth rates in different states. We analyze the magnitudes of these parameters in the empirical results.

To account for possible heteroskedasticity in the data, the empirical GARCH model is estimated using quasi-maximum likelihood estimation described in Bollerslev and Wooldridge (1992). The heteroskedasticity-consistent Bollerslev-Wooldridge standard errors are presented in parenthesis under coefficient estimates.

The model is initially estimated without any asymmetric effect components or control variables to analyze the effect of surprises and uncertainty on stock return dynamics on and around announcement days, the main interest of this paper. As a robustness check, we also estimate this basic empirical specification with several control variables both in mean and volatility such as the dividend yield, the risk-free rate and dummy variables for announcement days. Our model implies that the return should be a function of the price-dividend ratio. Hence, including these control variables makes the empirical specification more realistic and similar to the actual return equation implied by our model. In order to analyze the pure effect of announcements, we do not include these variables into the original empirical specification.

In order to analyze the asymmetric effect of news, we define positive unanticipated news as $u_t^+ \equiv u_t 1_{\{u_t>0\}}$ whereas negative unanticipated news is defined as $u_t^- \equiv -u_t 1_{\{u_t<0\}}$. We then estimate the empirical model by replacing the unanticipated news by measures of positive and negative unanticipated news.

One should note that by definition, the empirical measures of surprises and uncertainty are quarterly variables. When estimating the model with daily stock return data, we assume that the surprise and uncertainty are zero on non-announcement days.

6 Empirical Results

6.1 Simulation Results

Before we proceed to the analysis of the empirical results, we analyze whether our theoretical model is capable of generating dynamics in returns observed in the data. To do this, we simulate daily dividends from the theoretical model described in Section 2. To simplify our analysis, we assume that there are two states of the economy, high growth state and low growth state. We first estimate a two-state regime switching model of Hamilton (1989) using the quarterly US nominal GDP data described above. The estimates are scaled to their corresponding daily values by assuming 60 trading days in a quarter. We calibrate the parameters of the daily dividend growth process in Equation (2) to the corresponding estimates of the US nominal GDP data. Risk aversion parameter γ and the time impatience parameter β are set equal to 1.3 and 0.9992, respectively. Table 3 summarizes calibrated values of the model parameters.

[TABLE 3 ABOUT HERE]

We simulate 8330 daily observations with a public announcement every 60 days corresponding to a total number of 138 public announcements. The daily price-dividend ratio, investors' beliefs, daily returns, unanticipated news and uncertainty are calculated from the simulated daily dividends using the corresponding equations in Section 2. One should note that we employ only the first model-based measure in our simulation results. We do not calculate the second model-based measure or the survey-based measures since our theoretical model does not guide us on the construction of those measures. We scale the measures of unanticipated news and uncertainty by their standard deviation. Figure 5 presents simulated daily returns.

[FIGURE 5 ABOUT HERE]

Several facts emerge from the graph of the simulated returns. First of all, the volatility of returns is time-varying. In other words, there are periods of high volatility and low volatility. Hence, the claim that our model is capable of generating time-varying volatility is supported by our simulation results. Although it is not immediately clear from Figure 5, most extreme returns are realized on announcement days supporting our claim that the returns react to available new information released on the announcement day.

In order to analyze whether the implications of our model hold for simulated returns and whether the empirical specification is appropriate for our research questions, we estimate the empirical specification for simulated returns. Tables 4 and 5 summarize our estimation results for simulated returns.

[TABLES 4 and 5 ABOUT HERE]

The fact that the conditional volatility of simulated returns is time-varying as observed in Figure 5 is also supported by significant coefficient estimates of ARCH and GARCH terms. The coefficient estimates of unanticipated news and uncertainty also support the implications of our theoretical model. We defer the discussion of these empirical results and the intuition behind them to the next section. We compare estimation results for simulated returns with those for return on the equal-weighted CRSP portfolio in the next section.

6.2 Effect of GDP Announcements on the Stock Market Return

In this section, we analyze the effect of advance GDP announcements on daily returns on the equal-weighted CRSP portfolio. The empirical specification is estimated separately using the four measures described above. Table 6 summarizes the estimation results of our empirical model without any control variables.

[TABLE 6 ABOUT HERE]

First of all, the estimation results without any control variables support the implications of our model about the mean return. Our theoretical model implies a negative effect of surprises on the mean return on announcement days if investors are more risk averse than a log utility investor. The coefficient estimate of unanticipated news is negative with respect to all four measures and it is significant with respect to three of the four measures. These empirical results suggest that investors are more risk averse than log-utility. Hence, returns react negatively to positive unanticipated news in advance GDP announcements. In other words, a positive surprise in the GDP announcement decreases the mean return on the announcement day, whereas a negative surprise increases the mean return. The effect of surprises on the mean return on announcement days is robust to different measures of surprises. The results are stronger when the model is estimated with model-based measures. This may be due to the fact that model-based measures employ more recent information than survey-based measures as discussed in Section 5.

One should note that the advance GDP announcements are released 8:30 AM before the stock market opens on the announcement day. Hence, the empirical specification can be considered as a predictive model as well as an explanatory model. The economic significance of these empirical results is the predictive relationship between news in advance GDP announcements and the stock market's reaction. Significant coefficient estimates suggest that one can predict how the stock market will react on the announcement day after the GDP news is released. The empirical results for the first model-based measure of unanticipated news suggest that if there is a one percent positive standardized surprise about the state of the economy in the announcement, the mean stock market return will drop by 0.057% on that announcement day. A similar logic applies to other measures as well. The fact that the empirical specification is predictive might have important implications for financial decisions that investors face.

Not surprisingly, there are significant ARCH and GARCH effects in the conditional variance of daily returns. More importantly, uncertainty has a significant effect on the conditional volatility of returns on announcement days. The degree of uncertainty resolved on the announcement day decreases the conditional volatility of returns. This effect is significant and robust across different measures of uncertainty. The intuition behind this result is straightforward. The uncertainty about the current growth rate of the economy is resolved on the announcement day. Hence, the conditional volatility of returns react to the resolution of uncertainty. Since the investors are less uncertain about the growth rate of the economy, the conditional volatility is lower. In other words, the higher the degree of uncertainty resolved, the lower the conditional volatility of returns would be on announcement days. One should note that the empirical results are concerned with announcement days. The conditional volatility of returns on two announcement days would be different if the degrees of uncertainty resolved are different. The conditional volatility of returns on announcement days might still be higher than the conditional volatility on non-announcement days. The difference between announcement days and non-announcement days is the resolution of uncertainty on announcement days. Although we do not present the results here, the implications of our model for non-announcement days are inline with the existing literature (Veronesi (1999)). The conditional volatility of returns are higher during periods of high uncertainty.

We include the quadratic function of uncertainty to analyze whether there is a nonlinear relationship between uncertainty and conditional volatility. In models with model-based measures, uncertainty has a significant positive quadratic effect on announcement-day volatility. Although not significant at any conventional level, the effect of uncertainty on announcement-day volatility is also positive in models with survey-based measures. These results suggest that uncertainty about the announcement has a nonlinear effect on announcement-day volatility, as predicted by our theoretical model.

Although the empirical results suggest that our model is capable of predicting the right sign of reaction, it remains to be determined if it is capable of matching the magnitudes of the reaction. Therefore, we next compare the empirical results for the first model-based measures with the empirical results for simulated returns in Table 4. First of all, the mean of our simulated returns matches that of historical returns on equal-weighted CRSP portfolio. The volatility of simulated returns is smaller than that of market returns. However, the ARCH and GARCH coefficients in Table 4 closely match those in Table 6. More importantly, the magnitude of reaction to unanticipated news for simulated returns is close that for market returns. In other words, the coefficient estimates of u_t in Tables 4 and 6 are similar in sign and magnitude. Although the coefficient estimate of uncertainty in the variance equation for simulated returns has the same sign, it fails to match the magnitude. This fact is due to the smaller variance of our simulated returns compared to the variance of the market returns.

These initial results are promising and consistent with implications of our theoretical model, so we next analyze whether our initial results are robust to different empirical specifications and control variables.

6.3 Robustness Checks

In this section, we examine the extent to which our initial results might depend on the particular specification of Equations (31)-(32). We evaluate the robustness of our results either by changing the empirical specification or by including explanatory variables in the original specification.

In order to analyze whether the empirical results are robust to different empirical specifications, we first estimate an exponential GARCH (EGARCH) model proposed by Nelson (1991). The EGARCH specification estimated is similar to the GARCH specification described in Equations (31)-(32) except the conditional volatility is expressed in the following exponential form:

$$\log(\upsilon_t^2) = \theta_0 + \theta_1\omega_{t-1} + \theta_2\omega_{t-1}^2 + \theta_3\log(\upsilon_{t-1}^2) + \theta_4\left|\frac{e_{t-1}}{\upsilon_{t-1}}\right| + \theta_5\frac{e_{t-1}}{\upsilon_{t-1}} \tag{33}$$

One of the key advantages of Nelson's EGARCH specification is that it allows for asymmetric effects in the conditional volatility. The empirical results on conditional volatility might be due to the asymmetric effect of news on the conditional volatility. Hence, the EGARCH specification is appropriate to analyze whether the empirical results for conditional volatility is robust to an asymmetric GARCH specification. Another advantage of the EGARCH specification is that since Equation (33) describes the log of υ_t^2, the variance itself (υ_t^2) is guaranteed to be positive independent of parameter values. Table 7 summarizes the estimated coefficients of the EGARCH specification.

[TABLE 7 ABOUT HERE]

The coefficient estimates of the EGARCH specification are similar to the coefficients estimates of the original GARCH specification independent of the measure used to estimate the specification. The unanticipated news has a significant negative coefficient estimate whereas the degree of uncertainty resolved on the announcement day decreases the conditional volatility. In other words, the empirical results and the interpretation of these results are robust with respect to the empirical specification used.

The empirical specification could possibly include a variety of additional explanatory variables, such as leading, current and lagging values of the announcement-day dummy, current and lagged values of the daily risk-free rate and the daily dividend yield in both the mean and the conditional volatility equations. Table 8 summarizes the estimation results with leading and lagging values of the announcement-day dummies.

The model estimated is described by Equations (31)-(32) where $1_t^{(A)}$ is an indicator variable indicating the announcement day and $1_t^{(A-)}, 1_t^{(A+)}$ are unity on trading days that immediately precede and follow an announcement day, respectively.

[TABLE 8 ABOUT HERE]

Several interesting facts emerge from Table 8. The coefficient estimate of the effect of surprises on the mean announcement-day return remains negative and significant. Thus, the effect of surprises is robust to including the announcement-day dummy variables ($1^{(A-)}$, $1^{(A)}$ and $1^{(A+)}$). The announcement day dummy is significant for two measures of unanticipated news (first model-based and survey-based measures) suggesting that there is an additional effect of the announcement on the daily stock returns in addition to the unanticipated news in the announcement. This fact might be due to the failure of these two measures correctly measuring the unanticipated news. However, the second model-based measure has a significant coefficient while making the announcement day dummy insignificant. This fact suggests that the second model-based measure performs better in terms of measuring the unanticipated news. The resolution of uncertainty on announcement days has the same effect on the conditional volatility as in the original specifications. The degree of uncertainty resolved on the announcement day significantly decreases the conditional volatility when the empirical specification is estimated with model-based measures of uncertainty. Although the coefficient estimates are similar in sign and magnitude, the effect is only marginally significant for survey-based measures.

Although the announcement day dummy in the variance equation has a positive coefficient estimate with respect to all measures, it is not significant in any of the models. Hence, the conditional volatility of returns increases on GDP announcement days, but insignificantly. The results about the after-announcement dummy ($1_t^{(A+)}$) are mixed and suggest that the effect of the announcement on conditional volatility is not persistent. In other words, any effect that the announcement has on the conditional volatility is incorporated in the return dynamics on the announcement day. This result is in line with findings in the existing literature. On the other hand, the before-announcement dummy ($1_t^{(A-)}$) has a significant and negative effect on conditional volatility in all models. This result is consistent with the findings of Jones, Lamont, and Lumsdaine (1998) on bond market volatility. They dubbed the relatively low conditional volatility of bond returns before announcement days the “calm-before-the-storm”. Our findings suggest that calm-before-the-storm effects are present in the stock market around advance GDP announcement days.

We follow Flannery and Protopapadakis (2002) in adding the dividend yield and the risk-free rate as control variables to the return equation. Adding control variables to the return equation accounts for possibly time-varying expected returns. We also include lagged values of these control variables in the variance equation to account for possible forecastability of conditional volatility by these control variables. We include the lagged values of these control variables since they have to be measurable with respect to the information set on the previous day. Table 9 summarizes our estimation results with these control variables, where r_t^f and yld_t denote the risk-free rate and the dividend yield, respectively.

[TABLE 9 ABOUT HERE]

The effect of surprises on announcement-day returns is robust to including control variables to account for time-varying expected returns. With respect to three of the four measures, the surprise has a significant and negative effect on the mean announcement-day return as in the original specification. The annoucement-day dummy in the return equation becomes insignificant with respect to almost all measures when one controls for time-varying expected return. This result is in line with our model which implies that the mean stock return should only react to unanticipated news on announcement days. An insignificant coefficient estimate for the announcement day dummy suggest that the unanticipated news captures the whole effect of the announcement. Furthermore, the daily risk-free rate and the dividend yield have significant and negative effects on daily returns. The effect of uncertainty on announcement-day volatility remains the same with significant coefficient estimates with respect to the model-based measures. The calm-before-storm effect is robust to adding control variables to the variance equation. Lagged values of risk-free rate and dividend yield do not have significant effect on volatility in any of the models. Overall, our findings in Table 8 are robust to adding control variables, such as the risk-free rate and the dividend yield.

Although we do not present the results here, we examine the robustness of our results to several other specifications. Our results are similar to those presented in Tables 8 and 9. The effect of surprise on annoucement-day returns is robust in all specifications. The effect of uncertainty is robust in any specification with model-based measures.

To summarize, the empirical results are in line with the implications of our model. Our empirical results suggest that surprises have a negative effect on announcement-day returns and the degree of uncertainty resolved causes the conditional volatility to decrease on announcement days.

6.4 The Asymmetric Effect of GDP Announcements on the Stock Market Returns

Our theoretical model predicts that a positive unanticipated news not only has a negative effect on stock returns but also has a bigger absolute effect than a negative unanticipated news. Or equivalently, the stock returns react asymmetrically to unanticipated news. In this section, we analyze whether the empirical evidence presented above for the stock market's reaction to advance GDP announcements is asymmetric. In order to test for asymmetric effects, we replace the unanticipated news in the return equation of the empirical specification by positive (u_t^+) and negative (u_t^-) unanticipated news which are described in Section 5.3. We estimate the original empirical specification with control variables and four measures of positive and negative unanticipated news. One should note that the measures of positive and negative unanticipated news are in percentage terms and standardized by standard deviations of the corresponding measure of unanticipated news. Table 10 summarizes the empirical results for the asymmetric effect of unanticipated news.

[TABLE 10 ABOUT HERE]

First of all, one should note that the coefficient estimates of other variables are almost identical to those in Table 9. The estimates of interest in Table 10 are the coefficients of positive and negative unanticipated news. The coefficient estimate of positive unanticipated news is positive with respect to all measures, whereas the coefficient estimate of negative unanticipated news is positive. These empirical results supports the empirical findings in Table 6 that the effect of unanticipated news on stock returns is negative. However, the estimates are significant with respect to only model-based measures. The F-statistics in Table 10 report test statistics for the null hypothesis which states that the coefficients of positive and negative unanticipated news are equal in magnitude. For model-based measures of unanticipated news, we reject the null hypothesis suggesting that the effect of positive unanticipated news is bigger in magnitude than the effect of negative unanticipated news. This distinction is not as clear for the survey-based measures for which we fail to reject the null hypothesis. These empirical results agree with the implication of our theoretical model.

6.5 Effect of GDP Announcements on the Risk-Free Rate and the Excess Market Return

In this section, we analyze the effect of GDP announcements on the daily secondary market rate of 3-month US Treasury Bills and the excess market return defined as excess returns on the equal-weighted market portfolio over the risk-free rate. We estimate the empirical model described in Equations (31)-(32) for percentage daily risk-free rate scaled by 100 and percentage excess market return. Table 11 summarizes our estimation results for the risk-free rate.

[TABLE 11 ABOUT HERE]

The empirical results for the daily risk-free rate are somewhat mixed. The effect of unanticipated news is positive with respect most of the measures but significant only in the specification with the first model-based measure. Hence, when significant, a positive surprise about GDP increases the short-term interest rate on announcement days. When we control for the unanticipated part of the announcement, the announcement dummy variables have no significant effect on the mean risk-free rate on announcement days.

In the variance equation, the only variable that has significant coefficient estimates across different measures is the ARCH term. More importantly, the resolution of uncertainty on announcement days does not seem to have a clear effect on the conditional volatility of the risk-free rate. These mixed empirical results about the risk-free rate suggest that the empirical results for the excess market return will be mostly driven by the risky market return.

The empirical results for the effect of GDP announcements on stock market return and risk-free rate have immediate implications for the excess market return. The excess market return, defined as the difference between risky return and risk-free return, would react stronger to the unanticipated component of the announcement than risky return. This follows from negative reaction of risky returns and positive reaction of risk-free returns to the unanticipated news in the announcement. In other words, positive unanticipated news in the announcement would decrease the excess market return more strongly and significantly than the risky return. On the other hand, the effect of uncertainty is not immediately clear. The conditional volatility of the excess market return is a function of conditional volatilities of risky and risk-free returns and the conditional covariance between them. We expect conditional volatility of the excess market return to react similarly as the market return since the empirical results for the risk-free rate are mixed. Table 12 summarizes supporting empirical results for these conjectures about the excess market return.

[TABLE 12 ABOUT HERE]

As expected, the excess market return reacts similarly to advance GDP announcements as the risky return. Although not presented here, the effect of unanticipated news on the excess market return is also asymmetric. A positive unanticipated news has a bigger effect on the excess market return than a negative unanticipated news of the same magnitude. The intuition from risky return follows for the excess market return.

6.6 Does the Effect of Unanticipated News Persist?

Is there a delayed effect of GDP announcements on daily stock returns? Another way to ask the same question is "Is all unanticipated information released on advance GDP announcement days incorporated into prices on the announcement day?". The answer to this question might have important implications for market efficiency. In this section, we address this question by analyzing possible delayed effect of GDP announcements on daily market returns in our framework.

If all unanticipated news released on the announcement day is incorporated into asset prices, we would not expect a delayed effect in daily stock returns. On the other hand, if prices react to the announcement slower than the efficient market hypothesis predict, then we would expect a significant delayed effect of unanticipated news on daily stock returns. Our model, in line with the efficient market hypothesis, predicts that available new information released on announcement days is incorporated into prices on the announcement day.

The empirical specification employed to test for possible delayed effect of the announcement is similar to the specification described by Equations (31)-(32). We include lagged values of unanticipated news, u_{t-1}, in both the return and the variance equations along with control variables discussed before. Table 13 summarizes the empirical results.

[TABLE 13 ABOUT HERE]

Empirical results provide supporting evidence for our model and the efficient market hypothesis. The effect of lagged unanticipated news on the mean of returns is negative but insignificant. In other words, the unanticipated news in the announcement is incorporated into stock price on the announcement day and returns react to news only on the announcement day. The effect of unanticipated news after the initial reaction on the announcement day diminishes in one day. Similarly, the effect of lagged unanticipated news on conditional volatility of returns after the announcement is insignificant. The conditional volatility reacts to the resolution of uncertainty on the announcement day and the effect of the announcement on volatility diminishes on the announcement day. These findings are in line with the existing literature that finds that the effect of announcements are short-lived.

7 Sources of the Stock Market's Reaction to Announcements

The unanticipated news affects the stock market returns on announcement days through two possible channels: the change in expectations of future dividends and the change in expectations of future returns. The discount factor and the cash flows are closely linked due to the general equilibrium nature of our model. Hence, we do not distinguish between news about the discount factor or future dividends in our analysis. General equilibrium implies that both the discount factor and future cash flows react to news about future dividends. The main implication of our theoretical model is that the stock market returns react to news about the state or the growth rate of dividends. Hence, the unanticipated news should affect the stock market return through its effect on the change in expectations of future dividends. In this section, we decompose returns into three components: the expected return, the change in expectations of future dividends and the change in expectations of future returns. We analyze the effect of unanticipated news on these three components of returns. Our claim is that the change in expectations of future dividends should react to unanticipated news about the growth rate of the economy.

Following Campbell and Shiller (1988a) and Campbell (1991), we employ a log-linear approximation of log returns to decompose unexpected returns into different components. One can think of their model as a dynamic generalization of the Gordon growth model. Let r_t^* denote the log return in period t, defined as $r_t^* \equiv \log(1+r_t)$ where r_t is the return defined in Equation (10). By definition, the log return can be expressed as follows:

$$\begin{aligned} r_t^* &= \log(P_t + D_t) - \log(P_{t-1}) && (34) \\ &= p_t - p_{t-1} + \log(1 + \exp(d_t - p_t)) && (35) \end{aligned}$$

where p_t is the log price. The last term on the right-hand side of Equation (35) is a nonlinear function of the log dividend-price ratio. Using a first-order Taylor expansion, we obtain an approximation for log returns given as follows:

$$r_t^* \approx \theta + \rho p_t + (1-\rho)d_t - p_{t-1} \tag{36}$$

where θ and ρ are parameters of linearization defined by $\rho \equiv 1/(1+\exp(\overline{d-p}))$ and $\theta \equiv -\log(\rho) - (1-rho)\log(1/\rho - 1)$. $(\overline{d-p})$ is the average log dividend-price ratio. Imposing transversality condition, we can express asset returns as linear combinations of revisions in expected future dividends and returns as follows:

$$\begin{aligned} \eta_t \equiv r_t^* - E_{t-1}[r_t^*] &= E_t\left[\sum_{j=0}^{\infty} \rho^j \Delta d_{t+j}\right] - E_{t-1}\left[\sum_{j=0}^{\infty} \rho^j \Delta d_{t+j}\right] \\ &- \left(E_t\left[\sum_{j=1}^{\infty} \rho^j r_{t+j}^*\right] - E_{t-1}\left[\sum_{j=1}^{\infty} \rho^j r_{t+j}^*\right]\right) && (37) \\ &\equiv \eta_{d,t} - \eta_{r,t} && (38) \end{aligned}$$

This equation has the following economic interpretation. If the unexpected return, η_t, is positive, then either expected future dividend growth $\eta_{d,t}$ must be higher than previously expected, or the excess future returns $\eta_{r,t}$ must be lower than expected, or any combination of these two must hold true.

In order to identify the sources of the stock market's reaction on announcement days, we analyze the effect of unanticipated news on $\eta_{d,t}$ and $\eta_{r,t}$. We use the structural VAR(1) approach of Campbell and Shiller (1988b) and Campbell (1991) to obtain estimates of $\eta_{d,t}$ and $\eta_{r,t}$. Specifically, we specify a vector $\mathbf{x}_t$ whose first element is the daily stock return and whose second element is the daily dividend yield, a relevant forecasting variable for returns. The assumption that the VAR is first-order is not restrictive, since a higher-order VAR can always be stacked into first-order form. The following VAR is estimated to obtain $\eta_{d,t}$ and $\eta_{r,t}$ via GMM.

$$\mathbf{x}_t \equiv \begin{bmatrix} r_t \\ yld_t \end{bmatrix} = \mathbf{A_0} + \mathbf{A_1}\mathbf{x}_{t-1} + \boldsymbol{\xi}_t \tag{39}$$

The GMM estimates are numerically identical to standard OLS estimates, but GMM delivers a heteroskedasticity-consistent variance-covariance matrix. Table 14 presents VAR estimation results.

[TABLE 14 ABOUT HERE]

Let " $\hat{}$ " denote the estimated values, e.g. $\hat{\boldsymbol{\xi}}_t$ denote the residuals (or equivalently, one-period forecast errors) from the VAR estimation. By definition, $\hat{\eta}_{r,t}$ can be expressed as follows:

$$\hat{\eta}_{r,t} = \mathbf{e}_1' \sum_{j=1}^{\infty} \hat{\rho}^j \hat{\mathbf{A}}_1^j \hat{\boldsymbol{\xi}}_t = \mathbf{e}_1' \hat{\rho} \hat{\mathbf{A}}_1 (\mathbf{I} - \hat{\rho}\hat{\mathbf{A}}_1)^{-1} \hat{\boldsymbol{\xi}}_t \tag{40}$$

From Equation (38) the revision in expectations of future dividends, $\hat{\eta}_{d,t}$ can be treated as a residual:

$$\hat{\eta}_{d,t} = (r_t^* - \hat{E}_{t-1}[r_t^*]) + \hat{\eta}_{r,t} = \mathbf{e}_1'(\mathbf{I} + \hat{\rho}\hat{\mathbf{A}}_1(\mathbf{I} - \hat{\rho}\hat{\mathbf{A}}_1)^{-1})\hat{\boldsymbol{\xi}}_t \tag{41}$$

The returns can be decomposed into its components as follows: $r_t^* = \hat{E}_{t-1}[r_t^*] + \hat{\eta}_{d,t} - \hat{\eta}_{r,t}$. To disentangle the source of the stock market's reaction on announcement days, we regress the three components of returns on unanticipated news. Table 15 presents the empirical results.

[TABLE 15 ABOUT HERE]

As mentioned before, the unanticipated news about the growth rate of the economy affects the stock market return through two possible channels. The coefficient estimates of unanticipated news in estimation results for $\hat{\eta}_{d,t}$ and $\hat{\eta}_{r,t}$ with model-based measures are significant and negative. Hence, a positive unanticipated news has similar effects on the expectations of future dividends and future returns and decreases them significantly. However, one should note that a negative change in expectations of future returns has a positive effect on the stock market return due to the decomposition of return in Equation (38). In other words, if the expected future returns is lower than previously expected due to the unanticipated news, then stock market returns will increase. The overall effect of a positive unanticipated news on the stock market through the change in expectations of future returns is positive. On the other hand, a decrease in expectations of future dividends decreases the stock market return. Hence, the observed negative reaction of stock market returns to positive unanticipated news in advance GDP announcements is due to the change in expectations about future dividends on announcement days. Furthermore, the empirical results suggest that the effect of unanticipated news on future expected dividends dominates that on future expected returns.

8 Effect of "Employment Situation" Announcements on the Stock Market Return

So far, we have analyzed the effect of advance GDP announcements on the stock market return. The choice of GDP announcements is a natural one in our theoretical model since we derive implications about the news on the growth rate of the economy. GDP announcements are the most important announcement about the growth rate of the economy. However, one can easily consider the effect of news variables that are not perfectly correlated with the growth rate of the economy unlike GDP news. The implications of our model can be easily extended to news variable that provide imperfect information about the state of the economy. Employment news is one such news variable. It is considered as the most newsworthy announcement among various macroeconomic announcements. Boyd, Hu, and Jagannathan (2005) notes that it has frequently been the reference point of the Federal Reserve policy and the target of wide speculation on Wall Street. Li and Engle (1998) calls the employment announcements as the "king" of announcements and Flannery and Protopapadakis (2002) claims that the market "watches" it. In this section, we analyze the effect of employment news on the stock market return. The underlying assumption of this analysis is that the employment news provide information about the state and the growth rate of the economy. In particular, we assume that investors learn about the state of the economy through the employment news and analyze the effect of a change in their beliefs due to the employment announcement.

In this analysis, we focus on one type of employment announcement, namely monthly announcements of "The Employment Situation" from Bureau of Labor Statistics (BLS). Beginning of every month, the BLS releases, among other information, the nonfarm payroll employment and the unemployment rate in the previous quarter. These two estimates are arguably the most important figures in the Employment Situation announcement.

In order to obtain a proxy for investors' beliefs about the state of the economy as they observe the employment situation announcements, we estimate a Markov-switching vector autoregression (MS-VAR) of Krolzig (1997) for real-time monthly change in the nonfarm payroll employment and the unemployment rate. Real-time monthly the nonfarm payroll employment and the unemployment rate are available from the Federal Reserve Bank of Philadelphia. We assume that change in log nonfarm payroll employment and unemployment rate have a common state (the state of the economy) that follows a Markov chain with two possible states. Specifically, the joint process for the nonfarm payroll employment and the unemployment rate can be expressed as:

$$\begin{pmatrix} \Delta \log(NFEMP_t) \\ \Delta \log(UNEMP_t) \end{pmatrix} = \boldsymbol{\kappa}_{S_t} + \boldsymbol{\Omega}_{S_t}\boldsymbol{\xi}_t \tag{42}$$

where $NFEMP_t$ and $UNEMP_t$ are real-time values of the nonfarm payroll employment and the unemployment rate in month t, respectively. $S_t = 1, 2$ denotes the common state and $\boldsymbol{\kappa}_{S_t}$ and $\boldsymbol{\Omega}_{S_t}$ are the (2×1) mean vector and the (2×2) variance matrix as a function of the common state variable. For every employment situation announcement day, we first estimate the MS-VAR in Equation (42) using all available real-time data for the nonfarm payroll employment and the unemployment rate excluding the announcement. We next estimate it using all available data including the announcement. We construct model-based measures for unanticipated news about the state of the economy and uncertainty for employment news by the approach discussed in Section 5.1[12,13]. We estimate the empirical GARCH(1,1) specification described in

[12]The approach employed to construct measures of unanticipated news and uncertainty news for employment news is identical to the model-based approach for GDP news except the approach used for the construction of $\hat{\pi}_{n|n-1}$. We estimate a MS-VAR model for two variables (the nonfarm payroll employment and the unemployment rate) instead of a simple regime-switching model for one variable (GDP). The details of the estimation of MS-VAR can be found in the appendix and Krolzig (1997). In the first model-based measure of unanticipated news and uncertainty, we do not distinguish between the nonfarm payroll employment news and the unemployment rate news. This follows from the assumption of a common state for the nonfarm payroll employment and the unemployment rate. In other words, we assume investors learn about the state of the economy by observing the nonfarm payroll employment and the unemployment rate on employment situation announcement days. The unanticipated news in the employment situation announcements is about the state of the economy. However, in the second model-based measure, we distinguish between the nonfarm payroll employment news and the unemployment rate news. Similar to GDP measures, second model-based measures for employment news are related to the forecasts of change in the nonfarm payroll employment and the unemployment rate.

[13]We were not able to obtain necessary data to construct survey-based measures. The Survey of Professional Forecasters (SPF) data used to construct survey-based measures for advance GDP announcement is

Equations (31) and (32) for daily stock market returns with employment news instead of GDP news. Table 16 presents empirical results for the effect of employment news on daily stock market returns.

[TABLE 16 ABOUT HERE]

The effect of unanticipated employment news as measured by the first model-based measure on daily stock market returns is similar to the effect of unanticipated GDP news. A positive unanticipated news about the state of the economy in employment announcements has a negative effect on the stock market return. A one percent standardized positive surprise about the state of the economy in the employment news decreases the stock market return by 0.078% on employment situation announcement days. However, the effect of the resolution of uncertainty on the conditional volatility is not significant for employment situations announcement days. The conditional volatility of daily stock market returns decrease significantly before employment situation announcement days suggesting a calm-before-the-storm effect of employment announcements. On the other hand, when we distinguish between the nonfarm payroll employment news and the unemployment rate news on employment situation announcement days, we find that the stock market's reaction to employment situation announcements is due to unanticipated news in the nonfarm payroll employment. The coefficient estimate of unanticipated news in the nonfarm payroll employment is negative and significant whereas the coefficient estimate of unanticipated news in the unemployment rate is negative but insignificant. Furthermore, the coefficient estimate of uncertainty about the nonfarm payroll employment in the variance equation is negative and marginally[14] significant. These empirical results suggest that the implications of our theoretical model hold not only for news about the growth rate of the economy but also for news correlated with the growth rate.

9 Conclusion

In this paper, we analyze how the stock market reacts to news about fundamentals. Specifically, we analyze how the stock market reacts to scheduled public macroeconomic announcements that reveal information about the state of the economy. We develop a dynamic general equilibrium asset pricing model with periodic public announcements where investors learn about the unobserved state of the economy through dividend realizations and public announcements. Returns react significantly on announcement days only if there is a significant change in investors' beliefs due to the announcement. Furthermore, a positive unanticipated news about the state of the economy decreases the stock market return on announcement days if investors are more risk averse than log utility. The stock market reacts asymmetrically to unanticipated news. In other words, the effect of a positive unanticipated news is stronger than the effect of a negative unanticipated news of the same magnitude. On the other hand, the conditional volatility of returns reacts to the resolution of uncertainty on announcement days.

not suitable for the monthly employment announcements. First of all, forecasts from SPF are available on a quarterly basis whereas the employment figures are released on a monthly basis. Secondly, only survey data on the unemployment rate is available for the whole period of our sample. The quarterly forecasts of the nonfarm payroll employment have recently been added to the SPF and is available since the fourth quarter of 2003.On the other hand, monthly forecasts of the nonfarm payroll employment and the unemployment rate are available from survey data of Money Market Services International (MMS) since 1985. However, forecasts of individual forecasters necessary to construct the uncertainty measures were not available to the author at the time of this study. Although MMS survey data would be appropriate for the purposes of this study, we were not able to obtain individual forecaster data.

[14] at 11% confidence level

The higher the degree of uncertainty resolved on the announcement day, the smaller the conditional volatility will be. We claim that the resolution of uncertainty about the state of the economy is the main theoretical link between news about fundamentals and the behavior of conditional volatility on announcement days. Additionally, we find that the information revealed on announcement days is incorporated into the stock price in a single period. Using real-time data, we develop model-based and survey-based measures of unanticipated news and uncertainty to test the implications of our model. We find supporting evidence for our theoretical model in the aggregate stock market data. We claim that our model provides theoretical support for recent empirical findings about the effect of news on the stock market.

Our model is realistic and analytically tractable and most importantly suitable for the question addressed in this paper. It is possible to obtain analytical solutions to several possible extensions of our model. First of all, one can think of modeling consumption and dividend processes separately (Cecchetti, Lam, and Mark (1993)) to analyze possibly different effects of dividend and GDP announcements. Cecchetti, Lam, and Mark (1993) develop a representative agent model where consumption and dividends grow according to a regime-switching VAR. This framework is a partial equilibrium model and it would be more suitable for analyzing individual stocks rather than the aggregate stock market. Furthermore, in the framework of Cecchetti, Lam, and Mark (1993), one can think of the difference between consumption and dividends as labor income which would have implications for the effect of employment news on returns. Another possible generalization is to model dividends and the price of the consumption good. David and Veronesi (2004) show that analytical solutions to equilibrium asset prices are still available in this framework. One can easily use their model to analyze the effect of releases about interest rates, such as Federal Open Market Committee meetings.

One of the shortcomings of our model is lack of implications for volume on announcement days. A possible way to generate volume in this framework is information asymmetry among investors. Future research should focus on developing an asset pricing model with public announcements and asymmetric information about announcements among investors. Furthermore, our preliminary empirical results suggest that announcement about fundamentals have heterogenous effects on the cross-section of returns. Analyzing the effect of macroeconomic announcements on cross-section of returns might provide intuition for whether unanticipated news is a risk factor on announcement days.

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Figure 1: Time Line of GDP announcements from the BEA

The figure presents the time line of GDP announcements for the third quarter of 2003 as an example. The advance GDP estimate for the second quarter of 2003 is released on 07/31/03. The preliminary and final estimates for the second quarter of 2003 that are revisions to the advance estimate are released on 08/28/03 and 09/26/03, respectively. The advance GDP estimate for the third quarter of 2003 is released on 10/30/03. The time line of events are similar for every quarter. The figure also presents the data used to construct the model based measures for the advance GDP announcement day for the third quarter of 2003, i.e. 10/30/03. $\pi_{n|n-1}$ and $\mu_{i,n-1}$ for $i = 1, 2$ denote investors' forecasts of the state and the growth rate of the economy in different states using data available before the advance GDP announcement day. The forecasts for the third quarter of 2003 are constructed based on final estimates of GDP up to and including the second quarter of 2003. $\pi_{n|n}$ and $\mu_{i,n}$ for $i = 1, 2$ are the corresponding realized values of the forecasts and are constructed based on all available data including the advance GDP estimate for the third quarter of 2003.

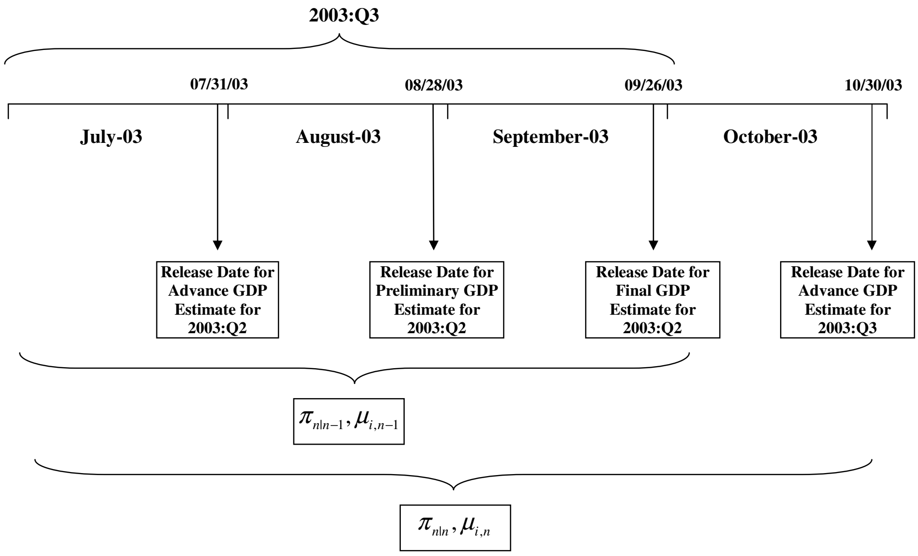
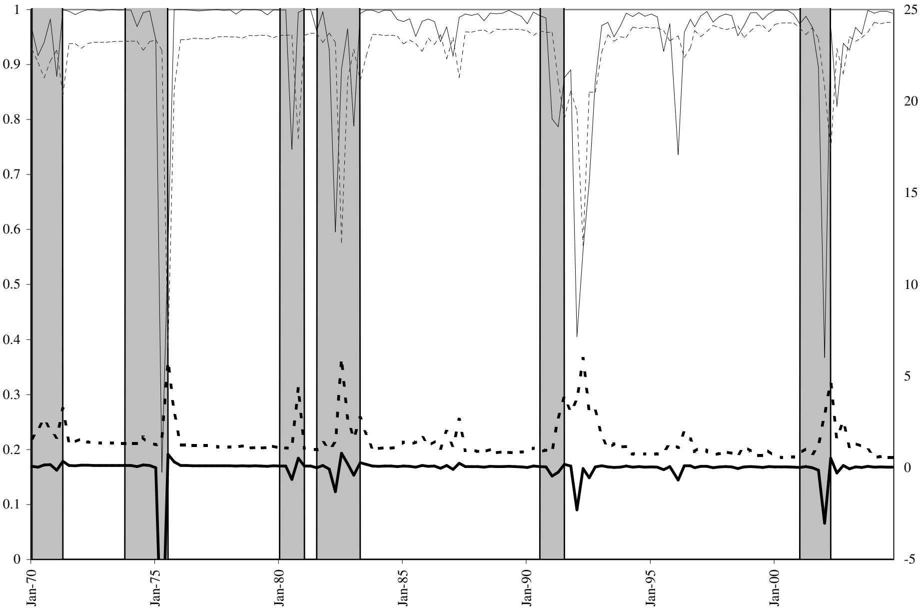


Figure 2: Model-based measures of surprise and uncertainty

Panel A presents the forecasts (thin dotted line) and the realizations (thin solid line) of the state of the economy whereas Panel B presents the forecasts (thin dotted line) and the realizations (thin solid line) of the growth rate of the economy using the model-based approach discussed in text. The figure also presents model-based measures of surprise (thick solid line) and uncertainty (thick dotted line) between 1970 and 2004 as described in 5.1. The vertical axis in Panel A is the probability of the high growth state, whereas the vertical axis in Panel B is the percentage growth rate of the economy. The shaded regions are the NBER recession periods.

Panel A: The First Model-Based Measures of Surprise and Uncertainty



Panel B: The Second Model-Based Measures of Surprise and Uncertainty

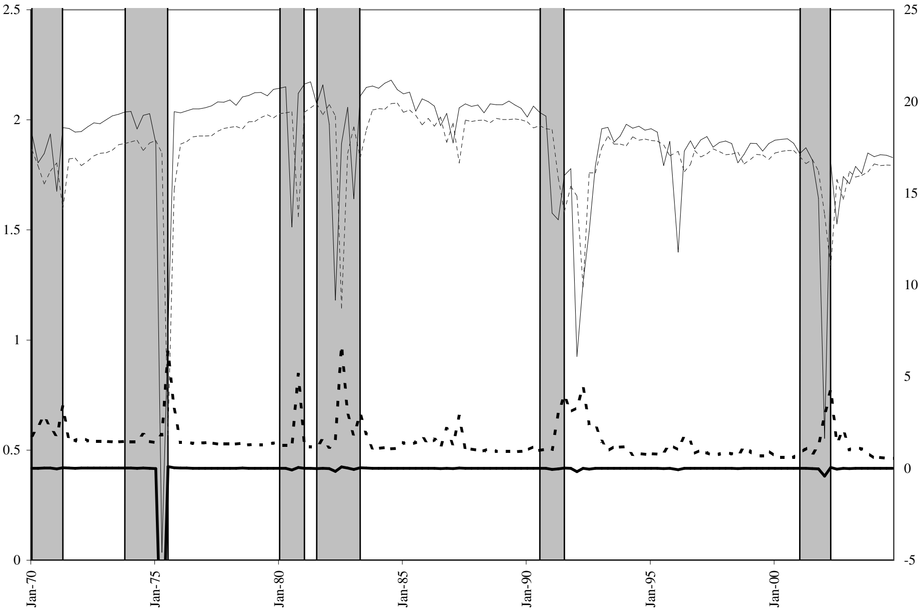
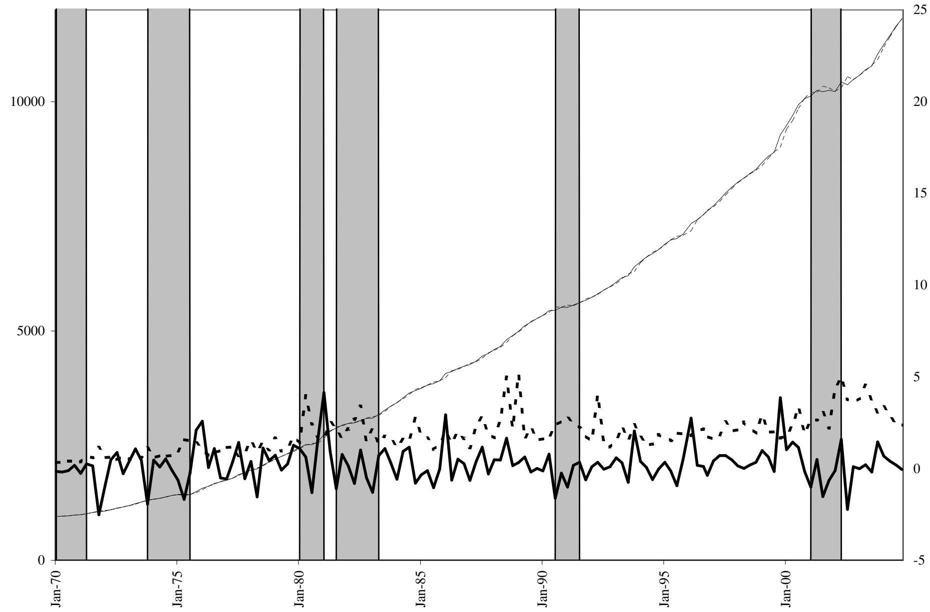


Figure 3: Survey-based measures of surprise and uncertainty

Panel A presents the forecasts (thin dotted line) and the realizations (thin solid line) of the level of nominal GDP whereas Panel B presents the forecasts (thin dotted line) and the realizations (thin solid line) of the growth rate of GDP using the survey-based approach discussed in text. The figure presents survey-based measures of surprise (thick solid line) and uncertainty (thick dotted line) between 1970 and 2004 as described in Section 5.2. The vertical axis in Panel A is the level of nominal US GDP in billion dollars, whereas the vertical axis in Panel B is the percentage growth rate of the economy. The shaded regions are the NBER recession periods.

Panel A: The First Survey-Based Measures of Surprise and Uncertainty



Panel B: The Second Survey-Based Measures of Surprise and Uncertainty

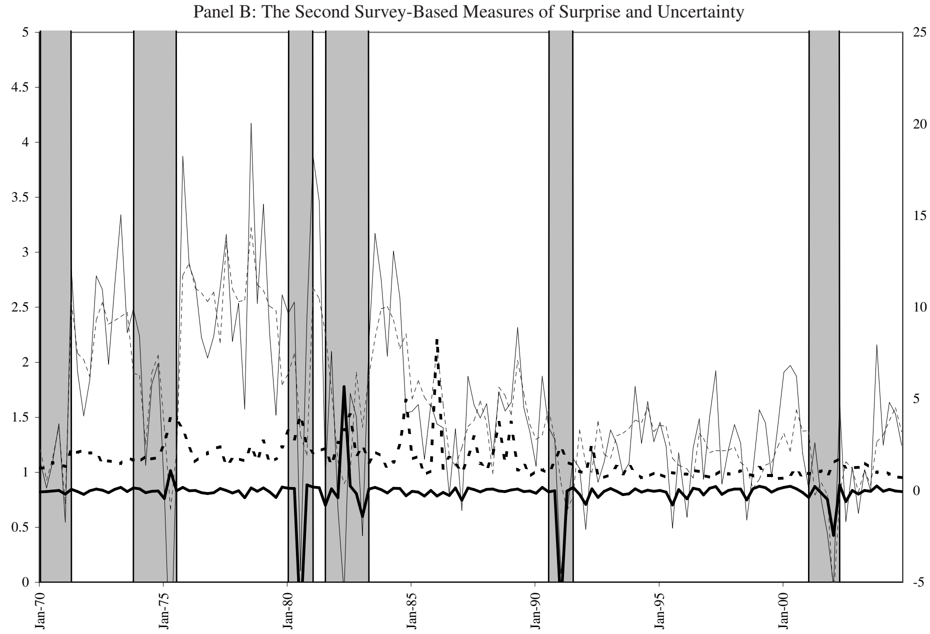


Figure 4: Time Line of Events in the Construction of Measures

The figure presents when different measures of unanticipated news and uncertainty would be available to investors for the third quarter of 2003 as an example. The survey-based measures of uncertainty is available on 08/22/03, the release date of the SPF. The model-based measure of uncertainty is available on 09/26/03, the release date of final GDP estimates for the second quarter of 2003. Both model-based and survey-based measures of unanticipated news is observed on 10/30/03, the advance GDP announcement day for the third quarter of 2003.

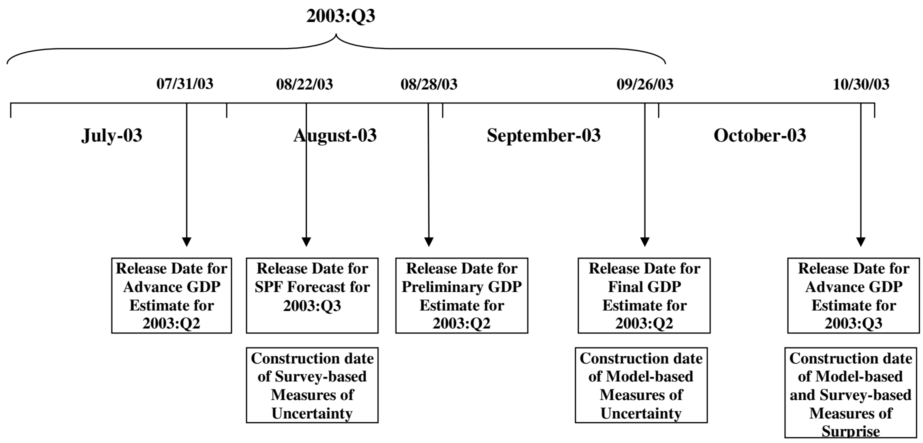


Figure 5: Simulated Daily Returns

The figure presents daily simulated returns calculated via Equation (10) from daily simulated dividend realizations. There are 8830 daily observations with 138 periodic (every 60 days) announcements about the state of the economy.

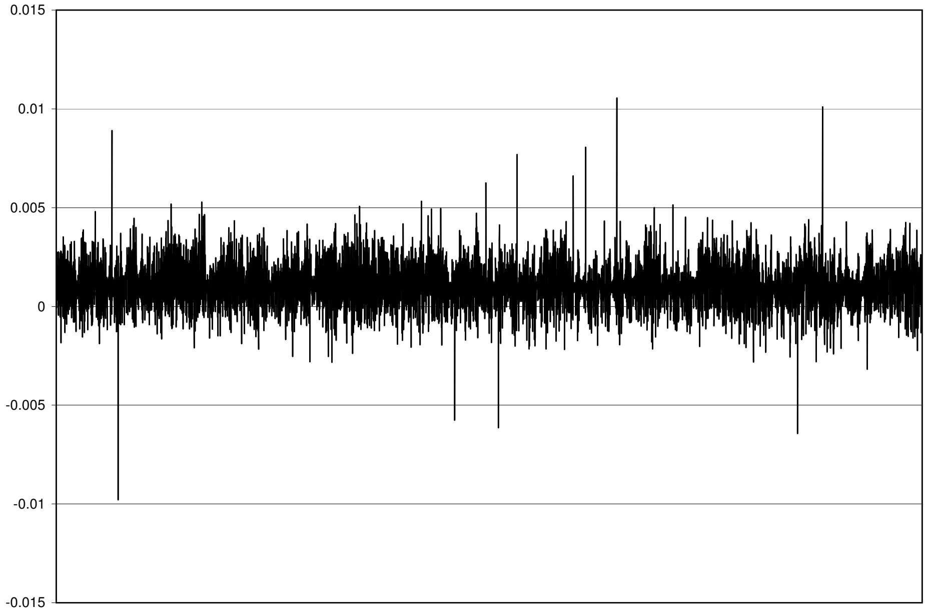


Table 1: Correlations between Different Measures of Unanticipated News, u

	Model Based 1	Model Based 2	Survey Based 1	Survey Based 2
Model Based 1	1			
Model Based 2	0.939	1		
Survey Based 1	0.207	0.170	1	
Survey Based 2	-0.010	-0.092	0.187	1

The table presents the correlation between different measures of unanticipated news for whole sample period between 1970 and 2004. First column denoted "Model-Based 1" presents the correlations between the first model-based measure of unanticipated news and other measures of unanticipated news. Similarly, the other columns present the correlations between different measures of unanticipated news.

Table 2: Correlations between Different Measures of Uncertainty, w

	Model Based 1	Model Based 2	Survey Based 1	Survey Based 2
Model Based 1	1			
Model Based 2	0.975	1		
Survey Based 1	0.071	0.005	1	
Survey Based 2	0.232	0.298	0.131	1

The table presents the correlation between different measures of uncertainty for whole sample period between 1970 and 2004. First column denoted "Model-Based 1" presents the correlations between the first model-based measure of uncertainty and other measures of uncertainty. Similarly, the other columns present the correlations between different measures of uncertainty.

Table 3: Calibrated Model Parameters

Parameter	Calibrated Value
γ	1.3
β	0.9992
μ_1	0.000307
μ_2	-0.000070
σ_1	0.001267
σ_2	0.001233
q_1	0.9
q_2	0.7

The table presents the calibrated values of the model parameters that are used to simulate daily dividend realizations. γ and β are the investor's risk aversion and time impatience parameters, respectively. γ and β are not calibrated but are assigned to reasonable values. μ_1 and μ_2 are the average growth rates of nominal US GDP in different states of the economy, whereas σ_1 and σ_2 are the corresponding standard deviations of the growth rates. First state is assumed to be the high growth state. q_1 and q_2 are the diagonal elements of the transition probability matrix. The two-state regime switching model discussed in the text is estimated using the whole sample.

Table 4: Estimation Results for Simulated Returns

Return Equation	
Constant	0.103
	(0.001)***
u_t	-0.029
	(0.001)***
Variance Equation	
Constant	4.5E-04
	(0.000)***
e^2_{t-1}	0.112
	(0.007)***
υ^2_{t-1}	0.854
	(0.011)***
ω_{t-1}	-9.4E-04
	(0.000)***
ω^2_{t-1}	4.5E-05
	(0.000)***

The table presents the coefficients estimates of the empirical specification described in Equations (31)-(32) for simulated returns. The return equation is Equation (31), whereas the variance equation is Equation (32). u_t is the unanticipated news about the state of the economy, whereas ω_{t-1} is investors' uncertainty about the announcement. e^2_{t-1} and υ^2_{t-1} are the ARCH and GARCH terms, respectively. The heteroskedasticity consistent asymptotic standard errors of the coefficient estimates are presented in parenthesis under the corresponding coefficient estimate. *** indicates a significant coefficient estimate at 1% confidence level, whereas ** and * indicate significant coefficient estimates at 5% and 10% confidence levels, respectively.

Table 5: Estimation Results for the Asymmetric Effect of News on Simulated Returns

Return Equation	
Constant	0.103
	(0.001)***
u_t^+	-0.030
	(0.001)***
u_t^-	0.029
	(0.001)***
Variance Equation	
Constant	4.5E-04
	(0.000)***
e_{t-1}^2	0.112
	(0.007)***
υ_{t-1}^2	0.854
	(0.011)***
ω_{t-1}	-9.4E-04
	(0.000)***
ω_{t-1}^2	4.5E-05
	(0.000)***
F-Statistic	0.002
	(0.001)***

The table presents the coefficients estimates of the empirical specification described in Equations (31)-(32) with asymmetric news effect for simulated returns. The return equation is Equation (31), whereas the variance equation is Equation (32). $u_t^{(+)}$ is positive unanticipated news and $u_t^{(-)}$ is negative unanticipated news about the state of the economy, whereas ω_{t-1} is investors' uncertainty about the announcement. F-statistic is the test statistic where the null hypothesis is the equality of the coefficient estimates of $u_t^{(+)}$ and $u_t^{(-)}$. e_{t-1}^2 and υ_{t-1}^2 are the ARCH and GARCH terms, respectively. The heteroskedasticity consistent asymptotic standard errors of the coefficient estimates are presented in parenthesis under the corresponding coefficient estimate. *** indicates a significant coefficient estimate at 1% confidence level, whereas ** and * indicate significant coefficient estimates at 5% and 10% confidence levels, respectively.

Table 6: The Effect of Advance GDP Announcements on the Stock Market Returns

	Model-Based 1	Model-Based 2	Survey-Based 1	Survey-Based 2
		Return Equation		
Constant	0.124	0.123	0.125	0.124
	(0.005)***	(0.005)***	(0.005)***	(0.005)***
u_t	-0.057	-0.055	-0.080	-0.036
	(0.008)***	(0.001)***	(0.049)*	(0.036)
		Variance Equation		
Constant	0.021	0.021	0.021	0.021
	(0.003)***	(0.003)***	(0.003)***	(0.003)***
e_{t-1}^2	0.191	0.190	0.190	0.192
	(0.019)***	(0.019)***	(0.019)***	(0.019)***
υ_{t-1}^2	0.776	0.778	0.778	0.776
	(0.018)***	(0.018)***	(0.018)***	(0.018)***
ω_{t-1}	-0.058	-0.058	-0.044	-0.034
	(0.022)***	(0.022)***	(0.021)**	(0.017)**
ω_{t-1}^2	0.010	0.010	0.005	0.002
	(0.006)*	(0.006)*	(0.005)	(0.003)

The table presents the coefficients estimates of the empirical specification described in Equations (31)-(32) for daily returns on equal-weighted CRSP portfolio. The return equation is Equation (31), whereas the variance equation is Equation (32). u_t is unanticipated news in advance GDP announcements, whereas ω_{t-1} is investors' uncertainty about the announcement. e_{t-1}^2 and υ_{t-1}^2 are the ARCH and GARCH terms, respectively. The first column denoted "Model-Based 1" presents the empirical results when the empirical specification is estimated with the first model-based measures. Similarly, the other columns present the estimation results when the empirical specification is estimated with the measure in the column heading. The heteroskedasticity consistent asymptotic standard errors of the coefficient estimates are presented in parenthesis under the corresponding coefficient estimate. *** indicates a significant coefficient estimate at 1% confidence level, whereas ** and * indicate significant coefficient estimates at 5% and 10% confidence levels, respectively.

Table 7: The Effect of Advance GDP Announcements on the Stock Market Returns (EGARCH Specification)

	Model-Based 1	Model-Based 2	Survey-Based 1	Survey-Based 2
		Return Equation		
Constant	0.117	0.117	0.118	0.117
	(0.006)***	(0.006)***	(0.006)***	(0.006)***
u_t	-0.053	-0.055	-0.094	-0.047
	(0.014)***	(0.009)***	(0.052)*	(0.033)
		Variance Equation		
Constant	-0.270	-0.249	-0.266	-0.269
	(0.022)***	(0.022)***	(0.022)***	(0.022)***
$\|e_{t-1}/\upsilon_{t-1}\|$	0.288	0.268	0.286	0.287
	(0.025)***	(0.025)***	(0.025)***	(0.025)***
e_{t-1}/υ_{t-1}	-0.066	-0.062	-0.065	-0.066
	(0.010)***	(0.009)***	(0.010)***	(0.010)***
$\log(\upsilon_{t-1}^2)$	0.949	0.954	0.950	0.949
	(0.007)***	(0.007)***	(0.007)***	(0.007)***
ω_{t-1}	-0.197	-0.224	-0.251	-0.111
	(0.091)**	(0.083)***	(0.096)***	(0.074)
ω_{t-1}^2	0.041	0.050	0.054	-0.002
	(0.021)*	(0.019)***	(0.026)**	(0.017)

The table presents the coefficients estimates of the empirical specification described in Equations (31) and (33) for daily returns on equal-weighted CRSP portfolio. The return equation is Equation (31), whereas the variance equation is Equation (33). u_t is unanticipated news in advance GDP announcements, whereas ω_{t-1} is investors' uncertainty about the announcement. $|e_{t-1}/\upsilon_{t-1}|$, e_{t-1}/υ_{t-1} and $\log(\upsilon_{t-1}^2)$ are the EGARCH terms. The first column denoted "Model-Based 1" presents the empirical results when the empirical specification is estimated with the first model-based measures. Similarly, the other columns present the estimation results when the empirical specification is estimated with the measure in the column heading. The heteroskedasticity consistent asymptotic standard errors of the coefficient estimates are presented in parenthesis under the corresponding coefficient estimate. *** indicates a significant coefficient estimate at 1% confidence level, whereas ** and * indicate significant coefficient estimates at 5% and 10% confidence levels, respectively.

Table 8: The Effect of Advance GDP Announcements on the Stock Market Returns (Including the Announcement-day Dummy Variables)

	Model-Based 1	Model-Based 2	Survey-Based 1	Survey-Based 2
		Return Equation		
Constant	0.120	0.120	0.121	0.121
	(0.005)***	(0.005)***	(0.005)***	(0.005)***
$1_t^{(A-)}$	0.065	0.061	0.062	0.067
	(0.037)*	(0.037)	(0.038)	(0.038)*
$1_t^{(A)}$	0.052	0.044	0.095	0.051
	(0.024)**	(0.038)	(0.040)**	(0.040)
$1_t^{(A+)}$	0.071	0.068	0.052	0.056
	(0.043)*	(0.044)	(0.044)	(0.044)
u_t	-0.086	-0.051	-0.096	-0.040
	(0.027)***	(0.003)***	(0.050)*	(0.031)
		Variance Equation		
Constant	0.024	0.021	0.021	0.021
	(0.003)***	(0.003)***	(0.003)***	(0.003)***
e_{t-1}^2	0.199	0.190	0.190	0.191
	(0.020)***	(0.019)***	(0.019)***	(0.019)***
υ_{t-1}^2	0.765	0.778	0.779	0.778
	(0.019)***	(0.018)***	(0.018)***	(0.018)***
$1_t^{(A-)}$	-0.076	-0.077	-0.076	-0.076
	(0.018)***	(0.017)***	(0.017)***	(0.017)***
$1_t^{(A)}$	0.065	0.075	0.084	0.024
	(0.056)	(0.067)	(0.088)	(0.058)
$1_t^{(A+)}$	0.019	0.011	0.005	-0.003
	(0.025)	(0.028)	(0.027)	(0.029)
ω_{t-1}	-0.081	-0.084	-0.074	-0.012
	(0.031)***	(0.051)*	(0.065)	(0.038)
ω_{t-1}^2	0.011	0.013	0.011	0.000
	(0.005)**	(0.009)	(0.011)	(0.006)

The table presents the coefficients estimates of the empirical specification described in Equations (31) and (32) for daily returns on equal-weighted CRSP portfolio. The return equation is Equation (31), whereas the variance equation is Equation (32). u_t is unanticipated news in advance GDP announcements, whereas ω_{t-1} is investors' uncertainty about the announcement. e_{t-1}^2 and υ_{t-1}^2 are the ARCH and GARCH terms, respectively. $1_t^{(A)}$ is a dummy variable that is equal to 1 if day t is an advance GDP announcement day. Similarly, $1_t^{(A-)}$ and $1_t^{(A+)}$ before and after the announcement day dummy variables. The first column denoted "Model-Based 1" presents the empirical results when the empirical specification is estimated with the first model-based measures. Similarly, the other columns present the estimation results when the empirical specification is estimated with the measure in the column heading. The heteroskedasticity consistent asymptotic standard errors of the coefficient estimates are presented in parenthesis under the corresponding coefficient estimate. *** indicates a significant coefficient estimate at 1% confidence level, whereas ** and * indicate significant coefficient estimates at 5% and 10% confidence levels, respectively.

Table 9: The Effect of Advance GDP Announcements on the Stock Market Returns (Including the Dividend Yield and the Risk-free Rate)

	Model-Based 1	Model-Based 2	Survey-Based 1	Survey-Based 2
		Return Equation		
Constant	0.2223	0.2228	0.2234	0.2225
	(0.014)***	(0.014)***	(0.014)***	(0.222)***
$1_t^{(A-)}$	0.0624	0.0636	0.0608	0.0666
	(0.037)*	(0.037)*	(0.037)	(0.067)*
$1_t^{(A)}$	0.0255	0.0213	0.0807	0.0367
	(0.033)	(0.035)	(0.039)**	(0.037)
$1_t^{(A+)}$	0.0595	0.0583	0.0441	0.0486
	(0.043)	(0.044)	(0.045)	(0.049)
r_t^f	-4.5829	-4.6187	-4.6492	-4.5993
	(0.764)***	(0.764)***	(0.768)***	(-4.599)***
yld_t	-3.3065	-3.3056	-3.2638	-3.2877
	(0.685)***	(0.684)***	(0.685)***	(-3.288)***
u_t	-0.0578	-0.0525	-0.0897	-0.0378
	(0.010)***	(0.004)***	(0.049)*	(-0.038)
		Variance Equation		
Constant	0.0230	0.0215	0.0206	0.0208
	(0.006)***	(0.006)***	(0.006)***	(0.021)***
e_{t-1}^2	0.1971	0.1928	0.1917	0.1921
	(0.019)***	(0.019)***	(0.019)***	(0.192)***
υ_{t-1}^2	0.7702	0.7763	0.7779	0.7773
	(0.018)***	(0.018)***	(0.018)***	(0.777)***
$1_t^{(A-)}$	-0.0837	-0.0826	-0.0821	-0.0826
	(0.017)***	(0.017)***	(0.017)***	(-0.083)***
$1_t^{(A)}$	0.0627	0.0690	0.0901	0.0163
	(0.058)	(0.062)	(0.095)	(0.016)
$1_t^{(A+)}$	0.0167	0.0155	0.0095	-0.0021
	(0.027)	(0.028)	(0.030)	(-0.002)
r_{t-1}^f	0.0883	0.0902	0.1207	0.1240
	(0.213)	(0.208)	(0.206)	(0.124)
yld_{t-1}	-0.2870	-0.2530	-0.2377	-0.2546
	(0.433)	(0.424)	(0.419)	(-0.255)
ω_{t-1}	-0.0737	-0.0780	-0.0835	-0.0047
	(0.038)*	(0.044)*	(0.072)	(-0.005)
ω_{t-1}^2	0.0104	0.0117	0.0132	-0.0011
	(0.007)	(0.008)	(0.012)	(-0.001)

The table presents the coefficients estimates of the empirical specification described in Equations (31) and (32) for daily returns on equal-weighted CRSP portfolio. The return equation is Equation (31), whereas the variance equation is Equation (32). u_t is unanticipated news in advance GDP announcements, whereas ω_{t-1} is investors' uncertainty about the announcement. e_{t-1}^2 and υ_{t-1}^2 are the ARCH and GARCH terms, respectively. $1_t^{(A)}$ is a dummy variable that is equal to 1 if day t is an advance GDP announcement day. Similarly, $1_t^{(A-)}$ and $1_t^{(A+)}$ before and after the announcement day dummy variables. r_t^f and yld_t are the risk-free rate and the dividend yield, respectively. The first column denoted "Model-Based 1" presents the empirical results when the empirical specification is estimated with the first model-based measures. Similarly, the other columns present the estimation results when the empirical specification is estimated with the measure in the column heading. The heteroskedasticity consistent asymptotic standard errors of the coefficient estimates are presented in parenthesis under the corresponding coefficient estimate. *** indicates a significant coefficient estimate at 1% confidence level, whereas ** and * indicate significant coefficient estimates at 5% and 10% confidence levels, respectively.

Table 10: The Asymmetric Effect of Advance GDP Announcements on the Stock Market Returns

	Model-Based 1	Model-Based 2	Survey-Based 1	Survey-Based 2
		Return Equation		
Constant	0.222	0.221	0.224	0.222
	(0.014)***	(0.014)***	(0.014)***	(0.222)***
$1_t^{(A-)}$	0.066	0.068	0.060	0.066
	(0.037)*	(0.037)*	(0.037)	(0.066)*
$1_t^{(A)}$	0.068	0.059	0.054	0.053
	(0.048)	(0.046)	(0.056)	(0.053)
$1_t^{(A+)}$	0.061	0.060	0.045	0.049
	(0.043)	(0.043)	(0.045)	(0.049)
r_t^f	-4.564	-4.538	-4.665	-4.597
	(0.766)***	(0.765)***	(0.768)***	(-4.597)***
yld_t	-3.322	-3.331	-3.260	-3.287
	(0.686)***	(0.687)***	(0.685)***	(-3.287)***
u_t^+	-0.412	-2.690	-0.059	-0.355
	(0.157)***	(1.050)**	(0.073)	(-0.355)
u_t^-	0.062	0.060	0.153	0.034
	(0.014)***	(0.013)***	(0.094)*	(0.034)
F-Statistic	4.584	6.233	0.458	1.330
	(0.032)**	(0.013)**	(0.498)	(0.249)
		Variance Equation		
Constant	0.026	0.027	0.021	0.021
	(0.006)***	(0.006)***	(0.006)***	(0.021)***
e_{t-1}^2	0.202	0.204	0.192	0.192
	(0.020)***	(0.020)***	(0.019)***	(0.192)***
υ_{t-1}^2	0.762	0.759	0.777	0.777
	(0.019)***	(0.019)***	(0.018)***	(0.777)***
$1_t^{(A-)}$	-0.088	-0.090	-0.082	-0.083
	(0.017)***	(0.017)***	(0.017)***	(-0.083)***
$1_t^{(A)}$	0.068	0.076	0.093	0.013
	(0.059)	(0.059)	(0.095)	(0.013)
$1_t^{(A+)}$	0.016	0.015	0.012	-0.004
	(0.026)	(0.026)	(0.031)	(-0.004)
r_{t-1}^f	0.089	0.098	0.122	0.124
	(0.219)	(0.221)	(0.206)	(0.124)
yld_{t-1}	-0.379	-0.420	-0.235	-0.255
	(0.448)	(0.454)	(0.419)	(-0.255)
ω_{t-1}	-0.084	-0.090	-0.089	-0.002
	(0.042)**	(0.040)**	(0.073)	(-0.002)
ω_{t-1}^2	0.013	0.013	0.014	-0.001
	(0.008)	(0.007)*	(0.012)	(-0.001)

The table presents the coefficients estimates of the empirical specification described in Equations (31) and (32) for daily returns on equal-weighted CRSP portfolio. The return equation is Equation (31), whereas the variance equation is Equation (32). $u_t^{(+)}$ and $u_t^{(-)}$ are respectively positive and negative unanticipated news, whereas ω_{t-1} is investors' uncertainty about the announcement. F-statistic is the test statistic where the null hypothesis is the equality of the coefficient estimates of $u_t^{(+)}$ and $u_t^{(-)}$. e_{t-1}^2 and υ_{t-1}^2 are the ARCH and GARCH terms, respectively. $1_t^{(A)}$ is a dummy variable that is equal to 1 if day t is an advance GDP announcement day. Similarly, $1_t^{(A-)}$ and $1_t^{(A+)}$ before and after the announcement day dummy variables. r_t^f and yld_t are the risk-free rate and the dividend yield, respectively. The first column denoted "Model-Based 1" presents the empirical results when the empirical specification is estimated with the first model-based measures. Similarly, the other columns present the estimation results when the empirical specification is estimated with the measure in the column heading. The heteroskedasticity consistent asymptotic standard errors of the coefficient estimates are presented in parenthesis under the corresponding coefficient estimate. *** indicates a significant coefficient estimate at 1% confidence level, whereas ** and * indicate significant coefficient estimates at 5% and 10% confidence levels, respectively.

Table 11: The Effect of Advance GDP Announcements on the Risk-free Rate

	Model-Based 1	Model-Based 2	Survey-Based 1	Survey-Based 2
		Return Equation		
Constant	1.571	1.572	1.579	1.590
	(0.001)***	(0.001)***	(0.001)***	(0.001)***
$1_t^{(A-)}$	-0.004	-0.003	-0.007	-0.005
	(0.003)	(0.005)	(0.004)*	(0.007)
$1_t^{(A)}$	-0.001	-0.001	-0.001	0.001
	(0.007)	(0.004)	(0.015)	(0.028)
$1_t^{(A+)}$	-0.001	-0.002	-0.004	-0.004
	(0.005)	(0.005)	(0.004)	(0.006)
u_t	0.022	0.046	-0.004	0.024
	(0.006)***	(0.032)	(0.008)	(0.017)
		Variance Equation		
Constant	0.001	0.001	0.001	0.005
	(0.000)***	(0.000)***	(0.000)***	(0.000)***
e_{t-1}^2	0.993	0.972	1.063	1.103
	(0.044)***	(0.045)***	(0.058)***	(0.021)***
υ_{t-1}^2	0.004	0.001	0.013	-0.130
	(0.044)	(0.046)	(0.054)	(0.021)***
$1_t^{(A-)}$	0.000	0.000	0.000	0.001
	(0.000)**	(0.000)	(0.000)	(0.001)
$1_t^{(A)}$	0.000	0.003	-0.004	-0.011
	(0.000)	(0.001)***	(0.001)***	(0.008)
$1_t^{(A+)}$	0.000	0.000	0.000	0.001
	(0.000)**	(0.000)***	(0.000)	(0.001)
ω_{t-1}	-0.001	-0.003	0.004	0.013
	(0.000)	(0.001)***	(0.001)***	(0.010)
ω_{t-1}^2	0.000	0.001	-0.001	-0.003
	(0.000)	(0.000)***	(0.000)***	(0.002)

The table presents the coefficients estimates of the empirical specification described in Equations (31) and (32) for daily risk-free rate. The return equation is Equation (31), whereas the variance equation is Equation (32). u_t is unanticipated news in advance GDP announcements, whereas ω_{t-1} is investors' uncertainty about the announcement. e_{t-1}^2 and υ_{t-1}^2 are the ARCH and GARCH terms, respectively. $1_t^{(A)}$ is a dummy variable that is equal to 1 if day t is an advance GDP announcement day. Similarly, $1_t^{(A-)}$ and $1_t^{(A+)}$ before and after the announcement day dummy variables. The first column denoted "Model-Based 1" presents the empirical results when the empirical specification is estimated with the first model-based measures. Similarly, the other columns present the estimation results when the empirical specification is estimated with the measure in the column heading. The heteroskedasticity consistent asymptotic standard errors of the coefficient estimates are presented in parenthesis under the corresponding coefficient estimate. *** indicates a significant coefficient estimate at 1% confidence level, whereas ** and * indicate significant coefficient estimates at 5% and 10% confidence levels, respectively.

Table 12: The Effect of Advance GDP Announcements on the Excess Market Returns

	Model-Based 1	Model-Based 2	Survey-Based 1	Survey-Based 2
		Return Equation		
Constant	0.222	0.222	0.223	0.222
	(0.014)***	(0.014)***	(0.014)***	(0.222)***
$1_t^{(A-)}$	0.063	0.064	0.061	0.067
	(0.037)*	(0.037)*	(0.037)	(0.067)*
$1_t^{(A)}$	0.029	0.021	0.081	0.037
	(0.033)	(0.035)	(0.039)**	(0.037)
$1_t^{(A+)}$	0.059	0.057	0.044	0.049
	(0.043)	(0.043)	(0.045)	(0.049)
r_t^f	-5.583	-5.571	-5.649	-5.599
	(0.764)***	(0.765)***	(0.768)***	(-5.599)***
yld_t	-3.307	-3.306	-3.264	-3.288
	(0.685)***	(0.685)***	(0.685)***	(-3.288)***
u_t	-0.056	-0.052	-0.090	-0.038
	(0.010)***	(0.003)***	(0.049)*	(-0.038)
		Variance Equation		
Constant	0.023	0.023	0.021	0.021
	(0.006)***	(0.006)***	(0.006)***	(0.021)***
e_{t-1}^2	0.198	0.197	0.192	0.192
	(0.019)***	(0.019)***	(0.019)***	(0.192)***
υ_{t-1}^2	0.769	0.770	0.778	0.777
	(0.018)***	(0.018)***	(0.018)***	(0.777)***
$1_t^{(A-)}$	-0.084	-0.084	-0.082	-0.083
	(0.017)***	(0.017)***	(0.017)***	(-0.083)***
$1_t^{(A)}$	0.058	0.064	0.090	0.016
	(0.058)	(0.060)	(0.095)	(0.016)
$1_t^{(A+)}$	0.016	0.014	0.010	-0.002
	(0.027)	(0.027)	(0.030)	(-0.002)
r_{t-1}^f	0.089	0.091	0.121	0.124
	(0.214)	(0.214)	(0.206)	(0.124)
yld_{t-1}	-0.295	-0.301	-0.238	-0.255
	(0.435)	(0.436)	(0.419)	(-0.255)
ω_{t-1}	-0.069	-0.072	-0.084	-0.005
	(0.036)*	(0.040)*	(0.072)	(-0.005)
ω_{t-1}^2	0.010	0.010	0.013	-0.001
	(0.006)	(0.007)	(0.012)	(-0.001)

The table presents the coefficients estimates of the empirical specification described in Equations (31) and (32) for daily excess returns on equal-weighted CRSP portfolio. The return equation is Equation (31), whereas the variance equation is Equation (32). u_t is unanticipated news in advance GDP announcements, whereas ω_{t-1} is investors' uncertainty about the announcement. e_{t-1}^2 and υ_{t-1}^2 are the ARCH and GARCH terms, respectively. $1_t^{(A)}$ is a dummy variable that is equal to 1 if day t is an advance GDP announcement day. Similarly, $1_t^{(A-)}$ and $1_t^{(A+)}$ before and after the announcement day dummy variables. r_t^f and yld_t are the risk-free rate and the dividend yield, respectively. The first column denoted "Model-Based 1" presents the empirical results when the empirical specification is estimated with the first model-based measures. Similarly, the other columns present the estimation results when the empirical specification is estimated with the measure in the column heading. The heteroskedasticity consistent asymptotic standard errors of the coefficient estimates are presented in parenthesis under the corresponding coefficient estimate. *** indicates a significant coefficient estimate at 1% confidence level, whereas ** and * indicate significant coefficient estimates at 5% and 10% confidence levels, respectively.

Table 13: The Persistence of the Effect of Advance GDP Announcements on the Stock Market Returns

	Model-Based 1	Model-Based 2	Survey-Based 1	Survey-Based 2
		Return Equation		
Constant	0.222	0.215	0.223	0.182
	(0.014)***	(0.014)***	(0.014)***	(0.182)***
$1_t^{(A-)}$	0.062	0.069	0.063	0.025
	(0.037)*	(0.037)*	(0.037)*	(0.025)
$1_t^{(A)}$	0.030	0.024	0.085	-0.008
	(0.033)	(0.036)	(0.039)**	(-0.008)
$1_t^{(A+)}$	0.059	0.060	0.040	0.045
	(0.043)	(0.044)	(0.047)	(0.045)
r_t^f	-4.595	-4.793	-4.658	-5.537
	(0.764)***	(0.766)***	(0.766)***	(-5.537)***
yld_t	-3.308	-3.642	-3.255	-3.838
	(0.685)***	(0.700)***	(0.684)***	(-3.838)***
u_t	-0.058	-0.340	-0.086	-0.072
	(0.010)***	(0.282)	(0.049)*	(-0.072)
u_{t-1}	**-0.011**	**-0.102**	**0.022**	**-0.012**
	(0.027)	**(0.122)**	**(0.047)**	**(-0.012)**
		Variance Equation		
Constant	0.023	0.039	0.020	0.078
	(0.006)***	(0.007)***	(0.006)***	(0.078)***
e_{t-1}^2	0.197	0.216	0.190	0.232
	(0.019)***	(0.020)***	(0.019)***	(0.232)***
υ_{t-1}^2	0.770	0.740	0.780	0.716
	(0.018)***	(0.020)***	(0.018)***	(0.716)***
$1_t^{(A-)}$	-0.083	-0.115	-0.082	-0.131
	(0.017)***	(0.018)***	(0.017)***	(-0.131)***
$1_t^{(A)}$	0.063	0.059	0.090	0.026
	(0.059)	(0.075)	(0.096)	(0.026)
$1_t^{(A+)}$	0.016	-0.006	0.007	-0.051
	(0.027)	(0.037)	(0.030)	(-0.051)
r_{t-1}^f	0.086	0.204	0.138	0.759
	(0.213)	(0.238)	(0.202)	(0.759)***
yld_{t-1}	-0.289	-0.782	-0.251	-1.913
	(0.434)	(0.493)	(0.415)	(-1.913)***
ω_{t-1}	-0.075	-0.065	-0.084	-0.058
	(0.039)*	(0.032)**	(0.073)	(-0.058)
ω_{t-1}^2	0.011	0.007	0.013	0.004
	(0.007)	(0.005)	(0.012)	(0.004)
u_{t-1}	**-0.005**	**0.224**	**0.017**	**-0.047**
	(0.014)	**(0.443)**	**(0.026)**	**(-0.047)**

The table presents the coefficients estimates of the empirical specification described in Equations (31) and (32) for daily returns on equal-weighted CRSP portfolio. The return equation is Equation (31), whereas the variance equation is Equation (32). u_t is unanticipated news in advance GDP announcements, whereas ω_{t-1} is investors' uncertainty about the announcement. u_{t-1} is the lagged value of the unanticipated news. e_{t-1}^2 and υ_{t-1}^2 are the ARCH and GARCH terms, respectively. $1_t^{(A)}$ is a dummy variable that is equal to 1 if day t is an advance GDP announcement day. Similarly, $1_t^{(A-)}$ and $1_t^{(A+)}$ before and after the announcement day dummy variables. r_t^f and yld_t are the risk-free rate and the dividend yield, respectively. The first column denoted "Model-Based 1" presents the empirical results when the empirical specification is estimated with the first model-based measures. Similarly, the other columns present the estimation results when the empirical specification is estimated with the measure in the column heading. The heteroskedasticity consistent asymptotic standard errors of the coefficient estimates are presented in parenthesis under the corresponding coefficient estimate. *** indicates a significant coefficient estimate at 1% confidence level, whereas ** and * indicate significant coefficient estimates at 5% and 10% confidence levels, respectively.

Table 14: Coefficient Estimates for the VAR

	r_t	yld_t
Constant	0.0006	0.0001
	(0.000)	(0.000)
r_{t-1}	0.3297	0.0002
	(0.018)	(0.000)
yld_{t-1}	-0.5010	0.1417
	(0.834)	(0.011)
R^2	0.1091	0.0201

The table presents the coefficients estimates of the VAR in Equation (39). The column headings denote the dependent variable whereas the row headings are the independent variables. R^2 denotes the adjusted R^2 of the estimation. The heteroskedasticity consistent asymptotic standard errors of the coefficient estimates are presented in parenthesis under the corresponding coefficient estimate. *** indicates a significant coefficient estimate at 1% confidence level, whereas ** and * indicate significant coefficient estimates at 5% and 10% confidence levels, respectively.

Table 15: Sources of the Stock Market's Reaction to Advance GDP Announcements

	Model-Based 1			Model-Based 2			Survey-Based 1			Survey-Based 2		
	$\hat{E}_{t-1}[r_t^*]$	$\hat{\eta}_{d,t}$	$\hat{\eta}_{r,t}$	$\hat{E}_{t-1}[r_t^*]$	$\hat{\eta}_{d,t}$	$\hat{\eta}_{r,t}$	$\hat{E}_{t-1}[r_t^*]$	$\hat{\eta}_{d,t}$	$\hat{\eta}_{r,t}$	$\hat{E}_{t-1}[r_t^*]$	$\hat{\eta}_{d,t}$	$\hat{\eta}_{r,t}$
Constant	0.084	0.000	0.000	0.084	0.000	0.000	0.084	0.000	0.000	0.084	0.000	0.000
	(0.004)***	(0.012)	(0.004)	(0.004)***	(0.012)	(0.004)	(0.004)***	(0.012)	(0.004)	(0.004)***	(0.012)	(0.004)
$1_t^{(A-)}$	0.030	-0.021	-0.006	0.030	-0.021	-0.006	0.030	-0.021	-0.006	0.030	-0.021	-0.006
	(0.025)	(0.093)	(0.031)	(0.025)	(0.093)	(0.031)	(0.025)	(0.093)	(0.031)	(0.025)	(0.093)	(0.031)
$1_t^{(A)}$	0.006	0.035	0.014	0.006	0.033	0.013	0.010	0.048	0.018	0.002	0.034	0.013
	(0.019)	(0.075)	(0.025)	(0.019)	(0.075)	(0.025)	(0.019)	(0.073)	(0.024)	(0.018)	(0.075)	(0.025)
$1_t^{(A+)}$	0.012	-0.012	-0.003	0.012	-0.012	-0.003	0.012	-0.012	-0.003	0.012	-0.012	-0.003
	(0.018)	(0.104)	(0.034)	(0.018)	(0.104)	(0.034)	(0.018)	(0.104)	(0.034)	(0.018)	(0.104)	(0.034)
u_t	-0.004	-0.087	-0.028	-0.006	-0.077	-0.025	-0.016	-0.038	-0.012	-0.033	-0.049	-0.016
	(0.010)	(0.024)***	(0.008)***	(0.002)***	(0.008)***	(0.003)***	(0.018)	(0.066)	(0.022)	(0.014)**	(0.045)	(0.015)

The table presents linear regression results for the components of the mean return on announcement day dummy variables and unanticipated news in advance GDP announcements with respect to different measures. The components are estimated by employing the approach discussed in text. $\hat{E}_{t-1}[r_t^*]$ is the estimated expected return given the information set at time $t-1$, whereas $\hat{\eta}_{d,t}$ and $\hat{\eta}_{r,t}$ are the change in expected future dividends and the change in expected future returns, respectively. u_t is unanticipated news in advance GDP announcements. $1_t^{(A)}$ is a dummy variable that is equal to 1 if day t is an advance GDP announcement day. Similarly, $1_t^{(A-)}$ and $1_t^{(A+)}$ before and after the announcement day dummy variables. The first three columns denoted "Model-Based 1" present the empirical results when the regression is estimated with the first model-based measure of unanticipated news. Similarly, the other blocks of columns present the empirical results when the regression is estimated with the measure in the column heading. The heteroskedasticity consistent asymptotic standard errors of the coefficient estimates are presented in parenthesis under the corresponding coefficient estimate. *** indicates a significant coefficient estimate at 1% confidence level, whereas ** and * indicate significant coefficient estimates at 5% and 10% confidence levels, respectively.

Table 16: The Effect of "Employment Situation" News on the Stock Market Return

	Model-Based 1	Model-Based 2
	Return Equation	
Constant	0.119	0.118
	(0.005)***	(0.005)***
$1_t^{(A-)}$	0.054	0.056
	(0.023)**	(0.023)**
$1_t^{(A)}$	0.135	0.119
	(0.028)***	(0.026)***
$1_t^{(A+)}$	-0.097	-0.108
	(0.031)***	(0.030)***
u_t	-0.078	-
	(0.017)***	-
u_t^{NFEMP}	-	-0.050
	-	(0.015)***
u_t^{UNEMP}	-	-0.042
	-	(0.040)
	Variance Equation	
Constant	0.021	0.021
	(0.003)***	(0.004)***
e_{t-1}^2	0.194	0.192
	(0.019)***	(0.019)***
v_{t-1}^2	0.773	0.772
	(0.019)***	(0.019)***
$1_t^{(A-)}$	-0.066	-0.065
	(0.016)***	(0.016)***
$1_t^{(A)}$	0.005	-0.011
	(0.089)	(0.037)
$1_t^{(A+)}$	0.010	0.028
	(0.034)	(0.037)
ω_{t-1}	0.032	-
	(0.127)	-
ω_{t-1}^2	0.007	-
	(0.028)	-
ω_{t-1}^{NFEMP}	-	-0.599
	-	(0.375)
ω_{t-1}^{UNEMP}	-	0.647
	-	(0.401)

The table presents the coefficients estimates of the empirical specification described in Equations (31) and (32) for daily returns on equal-weighted CRSP portfolio where the news is about the employment situation announcements. The return equation is Equation (31), whereas the variance equation is Equation (32). u_t is unanticipated news about the state of the economy in employment situation announcements, whereas ω_{t-1} is investors' uncertainty about the state of the economy. u_t^{NFEMP} and u_t^{UNEMP} are respectively unanticipated news about the change in the nonfarm payroll employment and the unemployment rate, whereas ω_{t-1}^{NFEMP} and ω_{t-1}^{UNEMP} are the corresponding uncertainty measures. e_{t-1}^2 and v_{t-1}^2 are the ARCH and GARCH terms, respectively. $1_t^{(A)}$ is a dummy variable that is equal to 1 if day t is an advance GDP announcement day. Similarly, $1_t^{(A-)}$ and $1_t^{(A+)}$ before and after the announcement day dummy variables. The first column denoted "Model-Based 1" presents the empirical results when the empirical specification is estimated with the first model-based measures about the state of the economy. Similarly, the other column presents the estimation results when we distinguish between the nonfarm payroll employment news and the unemployment rate news. The heteroskedasticity consistent asymptotic standard errors of the coefficient estimates are presented in parenthesis under the corresponding coefficient estimate. *** indicates a significant coefficient estimate at 1% confidence level, whereas ** and * indicate significant coefficient estimates at 5% and 10% confidence levels, respectively.

A Proofs

Proof of Lemma 1. In this proof, for convenience, we refer to the time period between the previous announcement and the upcoming announcement as the current "quarter". Investors form their beliefs about the current state of the economy by observing two sources of information, the previous announcement about the state of the economy in the previous quarter and dividend realizations.

Case 1. ($t = T_{n-1}$): Note that on the (n-1)$^{\text{th}}$ announcement day, T_{n-1}, the only relevant variable about the state of the economy in the upcoming quarter in investors' information set is the (n-1)$^{\text{th}}$ announcement which reveals the true state of the economy in the previous quarter. Having observed the announcement, investors form their prior beliefs about the current state of the economy based on the law of motion of the state variable, z_n. If the (n-1)$^{\text{th}}$ reveals that economy has been in state j, i.e. $z_{n-1} = j$, the probability of switching to state i is given by q_{ji}, the ji$^{\text{th}}$ element of the transition probability matrix of z_n, $\mathbf{Q}$. On the announcement day, investors prior beliefs about the current state of the economy solely depends on the previous announcement. Hence, the equation in the first case is a function of only the previous announcement not dividend realizations.

Case 2. ($T_{n-1} < t < T_n$): Having observed the previous announcement at time T_{n-1}, investors update their beliefs through dividend realizations according to Bayes' rule. Recall that the probability of being in state i, $\pi_{it} = \Pr(z_n = i|\mathcal{F}_t)$.

$$\begin{aligned}
\pi_{it} &= \Pr(z_n = i|\Delta d_t, \mathcal{F}_{t-1}) && (43)\\
&= \frac{\Pr(\Delta d_t|z_n = i, \mathcal{F}_{t-1})\Pr(z_n = i|\mathcal{F}_{t-1})}{\Pr(\Delta d_t|\mathcal{F}_{t-1})} && (44)\\
&= \frac{\Pr(\Delta d_t|z_n = i, \mathcal{F}_{t-1})\Pr(z_n = i|\mathcal{F}_{t-1})}{\sum_{j=1}^{N}\Pr(\Delta d_t|z_n = j, \mathcal{F}_{t-1})\Pr(z_n = j|\mathcal{F}_{t-1})} && (45)\\
&= \frac{\phi(\frac{\Delta d_t-\mu_i}{\sigma_i})\pi_{i,t-1}}{\sum_{j=1}^{N}\phi(\frac{\Delta d_t-\mu_j}{\sigma_j})\pi_{j,t-1}} && (46)
\end{aligned}$$

where $\phi(\cdot)$ is the standard normal density function. Equation (43) follows from the definition of $\mathcal{F}_t$. Equation (44) and (45) follow from Bayes' rule and law of total probability, respectively[15]. Note that, by definition, $\pi_{j,t-1} = \Pr(z_n = j|\mathcal{F}_{t-1})$. Equation (46) follows from the law of motion for dividend growth in Equation (2).

Case 2. ($t = T_n$): On the announcement day, T_n, investors observe the true growth of the economy. Therefore, the probability of being in state i is either 1 or 0 depending on the announcement, hence the indicator function. This completes the proof. □

Proof of Lemma 2. By recursive substitution of future prices into Euler equation in (7), the price of the risky asset can be expressed as a discounted sum of expected future dividends where the discount factor is the intertemporal marginal rate of substitution:

$$P_t = E_t\left[\sum_{\tau=1}^{\infty}\beta^{\tau}\frac{U'(C_{t+\tau})}{U'(C_t)}D_{t+\tau}\right] \tag{47}$$

Imposing the equilibrium condition, $C_t = D_t$, substituting the functional form for the utility function and rearranging the terms, the price-dividend ratio at time t can be expressed as follows:

$$\frac{P_t}{D_t} = E_t\left[\sum_{\tau=1}^{\infty}\beta^{\tau}\left(\frac{D_{t+\tau}}{D_t}\right)^{1-\gamma}\right] \tag{48}$$

The infinite sum in Equation (48) can be expressed as a sum of two terms, sum of discounted future dividends until the upcoming announcement day and sum of discounted future dividends

[15] Recall that Bayes' rule is $\Pr(A|B,C) = \frac{\Pr(B|A,C)\Pr(A|C)}{\Pr(A|C)}$

after the upcoming announcement day. The price-dividend ratio can be expressed as follows:

$$\frac{P_t}{D_t} = \sum_{\tau=1}^{T_n-t} \beta^{\tau} E_t\left[\left(\frac{D_{t+\tau}}{D_t}\right)^{1-\gamma}\right] + \beta^{T_n-t} E_t\left[\left(\frac{D_{T_n}}{D_t}\right)^{1-\gamma} \frac{P_{T_n}}{D_{T_n}}\right] \tag{49}$$

Conditioning on the current state, the following holds:

$$\begin{aligned} \frac{P_t}{D_t} &= \sum_{j=1}^{N} \sum_{\tau=1}^{T_n-t} \beta^{\tau} E_t\left[\left(\frac{D_{t+\tau}}{D_t}\right)^{1-\gamma} \middle| z_n = j\right] \pi_{jt} \\ &+ \sum_{j=1}^{N} \beta^{T_n-t} E_t\left[\left(\frac{D_{T_n}}{D_t}\right)^{1-\gamma} \middle| z_n = j\right] E_t\left[\frac{P_{T_n}}{D_{T_n}} \middle| z_n = j\right] \pi_{jt} \end{aligned} \tag{50}$$

where Equation (50) follows from law of total probability and conditional independence of $\frac{D_{T_n}}{D_t}$ and $\frac{P_{T_n}}{D_{T_n}}$ when the conditioning information is the current state variable. Note that for any $t \in [T_{n-1}, T_n]$ and $\tau \in [1, T_n - t]$, we have

$$\begin{aligned} E_t\left[\left(\frac{D_{t+\tau}}{D_t}\right)^{1-\gamma} \middle| z_n = j\right] &= E_t[\exp((1-\gamma)\mu_j \tau + (1-\gamma)\sigma_j \sum_{l=1}^{\tau} \varepsilon_{t+l})] && (51) \\ &= \exp((1-\gamma)\mu_j + (1-\gamma)^2 \sigma_j^2/2)^{\tau} && (52) \\ &\equiv (e^{a_j})^{\tau} && (53) \end{aligned}$$

where $a_j \equiv (1-\gamma)\mu_j + (1-\gamma)^2\sigma_j^2/2$. Equation (51) follows from the law of motion for the dividend growth rate. Equation (52) follows from the formula for the expectation of a lognormal variable where the mean and variance of the normal variable are $(1-\gamma)\mu_j\tau$ and $(1-\gamma)^2\sigma_j^2\tau$, respectively. The price-dividend ratio can be expressed as:

$$\begin{aligned} \frac{P_t}{D_t} &= \sum_{j=1}^{N} \sum_{\tau=1}^{T_n-t} (\beta e^{a_j})^{\tau} \pi_{jt} + \sum_{j=1}^{N} (\beta e^{a_j})^{T_n-t} E_t\left[\frac{P_{T_n}}{D_{T_n}} \middle| z_n = j\right] \pi_{jt} \\ &= \sum_{j=1}^{N} \left(\frac{(\beta e^{a_j})^{T_n-t+1} - 1}{\beta e^{a_j} - 1} - 1\right) \pi_{jt} + \sum_{j=1}^{N} (\beta e^{a_j})^{T_n-t} E_t\left[\frac{P_{T_n}}{D_{T_n}} \middle| z_n = j\right] \pi_{jt} \end{aligned} \tag{54}$$

The price-dividend ratio on the (n-1)th announcement day can be expressed as follows by setting $t = T_{n-1}$:

$$\frac{P_{T_{n-1}}}{D_{T_{n-1}}} = \sum_{j=1}^{N} \left(\frac{(\beta e^{a_j})^{T+1} - 1}{\beta e^{a_j} - 1} - 1\right) q_{z_{n-1},j} + \sum_{j=1}^{N} (\beta e^{a_j})^{T} E_t\left[\frac{P_{T_n}}{D_{T_n}} \middle| z_n = j\right] q_{z_{n-1},j} \tag{55}$$

Equation (55) follows from the fact that $\pi_{j,T_{n-1}} = \sum_{l=1}^{N} q_{lj} 1_{\{z_{n-1}=l\}} = q_{z_{n-1},j}$ and $T_n - T_{n-1} = T$.

In order to solve the difference equation in (55), we conjecture a solution for the price-dividend ratio on announcement days of the following form:

$$\frac{P_{T_n}}{D_{T_n}} = \lambda_{z_n} \quad \text{for } n = 1, 2, \ldots \text{ and } z_n = 1, 2, \ldots, N \tag{56}$$

Plugging in the conjecture in Equation (56), we obtain the following system of N linear equations in N variables, $(\lambda_1, \ldots, \lambda_N)$:

$$\lambda_i = \sum_{j=1}^{N} \left(\frac{(\beta e^{a_j})^{T+1} - 1}{\beta e^{a_j} - 1} - 1\right) q_{ij} + \sum_{j=1}^{N} (\beta e^{a_j})^{T} \lambda_j q_{ij} \tag{57}$$

for $i = 1, 2, \ldots, N$. To reduce notation, we define a $N \times 1$ vector, $\mathbf{G}$, whose j^{th} element, g_j, is given by $g_j = \frac{(\beta e^{a_j})^{T+1}-1}{\beta e^{a_j}-1} - 1$ and a $N \times N$ diagonal matrix, $\mathbf{H}$, whose i^{th} diagonal element, h_i, is given by $h_i = (\beta e^{a_i})^T$. The system of equations in (57) can be expressed as follows:

$$\lambda = \mathbf{QG} + \mathbf{HQ}\lambda \tag{58}$$

Solving for the vector λ, we obtain the price-dividend ratio on announcement days in Lemma 2. This completes the proof. □

Proof of Proposition 1. Proof of Proposition follows from Equation (54). Note that $E_t[\frac{P_{T_n}}{D_{T_n}}|z_n = j] = \lambda_j$ from the result in Lemma 2. Plugging in, we obtain Equation (9) for the price-dividend ratio on non-announcement days. □

Proof of Corollary 1. Rearranging terms in the basic return equation, we obtain the following:

$$r_t = \frac{P_t + D_t - P_{t-1}}{P_{t-1}} = \frac{P_t/D_t + 1}{P_{t-1}/D_{t-1}} \frac{D_t}{D_{t-1}} - 1 \tag{59}$$

Plugging in the law of motion for the dividend growth in Equation (2) and the closed from solutions for the price-dividend ratio in Equation (9), we obtain the formula in Corollary 1. □

Proof of Proposition 2. Equation (14) follows immediately from the definition of returns and price-dividend ratio in Equation (9). The price-dividend ratio takes one of the two values depending on the state of the economy revealed on the announcement day. In other words, if the announcement reveals a high growth state for the economy, the price-dividend ratio on the announcement day, P_{T^*}/D_{T^*} is equal k_1. Otherwise, it is equal k_2. The return on the announcement day can be expressed as:

$$r_{T^*} = \frac{(k_1 1_{\{z_{T^*}=1\}} + k_2 1_{\{z_{T^*}=2\}} + 1)e^{\mu_{z_{T^*}} + \sigma\varepsilon_{T^*}}}{k_1 \pi_{T^*-1} + k_2(1 - \pi_{T^*-1})} - 1 \tag{60}$$

Expected return on the announcement day can be expressed as follows:

$$\begin{aligned}
E_{T^*-1}[r_{T^*}] &= E_{T^*-1}\left[\frac{(k_1 1_{\{z_{T^*}=1\}} + k_2 1_{\{z_{T^*}=2\}} + 1)e^{\mu_{z_{T^*}} + \sigma\varepsilon_{T^*}}}{k_1 \pi_{T^*-1} + k_2(1 - \pi_{T^*-1})} - 1\right] \\
&= \sum_{i=1}^{2} \frac{k_i + 1}{k_1 \pi_{T^*-1} + k_2(1 - \pi_{T^*-1})} E_{T^*-1}[e^{\mu_i + \sigma\varepsilon_{T^*}}] \Pr(z_{T^*} = i|\mathcal{F}_{T^*-1}) - 1
\end{aligned}$$

It is straightforward to obtain Equation (15) in Proposition 2 by plugging $E_{T^*-1}[e^{\mu_i + \sigma\varepsilon_{T^*}}] = e^{\mu_i + \sigma^2/2}$. On the other hand, the conditional volatility of returns on announcement days can be written as $var_{T^*-1}[r_{T^*}] = E_{T^*-1}[r_{T^*}^2] - (E_{T^*-1}[r_{T^*}])^2$. Plugging in the values for the conditional expectations, we obtain Equation (16). □

Proof of Proposition 3.

1. This follows directly from Proposition 2 and the definition of unanticipated news. Plugging in the definition and rearranging, we obtain return on announcement day as a function of unanticipated news.
2. When $\mu_1 > \mu_2$, it is relatively easy to show that $\gamma > 1$ implies that $k_2 - k_1 > 0$. Hence, the multiplicative factor in front of unanticipated news is positive when the announcement is positive, i.e. $z_{T^*} = 1$. Since return on announcement day is inversely related to unanticipated news, a positive coefficient on unanticipated news implies a negative relation between returns and unanticipated news. A similar argument holds for the case of negative announcement, i.e. $z_{T^*} = 2$. The reserve inequality holds when $\gamma < 1$, i.e. $k_2 - k_1 < 0$. Hence the opposite holds. In other words, a positive unanticipated news has a positive effect on returns on announcement days.

3. It follows directly from the return equation in the first implication. If $(k_1 + 1)e^{\mu_1} > (k_2 + 1)e^{\mu_2}$, then r_{T*} is greater for the same magnitude of unanticipated news when the announcement reveals positive news (i.e. $z_{T*} = 1$). In other words, if the inequality holds, the absolute effect of a positive unanticipated news is greater that that of a negative unanticipated news of the same magnitude.

□

Proof of Proposition 4. This follows directly from Proposition 2 and the definition of uncertainty, ω_t. □

B Estimation of Markov Regime Switching Vector Autoregressions (MS-VAR)

In this section, we discuss the algorithm employed to estimate the MS-VAR in Equation (42). The Markov regime switching model of Hamilton (1989) can be considered as a special case of an MS-VAR where the number of variables in the vector autoregression is one. Hence, a special case of the estimation approach discussed here is used to estimate the empirical model in Equation (21)[16].

The conditional likelihood of an MS-VAR can be calculated recursively similar to GARCH estimation. In this algorithm, the focus is on the conditional probability of observing a state rather than the switching probabilities between states. The conditional probability of observing a state is the weight on the mixture components. In its most general form, the specification for an MS(M)-VAR(P) of a K-dimensional vector of variables, $\mathbf{Y}_t = (Y_{1t}, \ldots, Y_{Kt})'$, where M is the number of states and P is the order of the vector autoregression, can be expressed as follows:

$$\mathbf{Y}_t = \begin{cases} \mathbf{A}_{01} + \mathbf{A}_{11}\mathbf{Y}_{t-1} + \ldots + \mathbf{A}_{p1}\mathbf{Y}_{t-P} + \mathbf{\Sigma}_1^{1/2}\mathbf{u}_t, & \text{if } S_t = 1 \\ \vdots & \vdots \\ \mathbf{A}_{0M} + \mathbf{A}_{1M}\mathbf{Y}_{t-1} + \ldots + \mathbf{A}_{PM}\mathbf{Y}_{t-P} + \mathbf{\Sigma}_M^{1/2}\mathbf{u}_t, & \text{if } S_t = M \end{cases} \tag{61}$$

for $t = 1, \ldots, T$ and $\mathbf{Y}_0, \ldots, \mathbf{Y}_{1-P}$ are fixed. $\mathbf{u}_t$ is a multivariate standard normal random variable, i.e. $\mathbf{u}_t \sim NID(\mathbf{0}, \mathbf{I}_K)$. Let $A_m(L) = \mathbf{I}_K - \mathbf{A}_{1m}L - \ldots - \mathbf{A}_{Pm}L^P$ denote the $(K \times K)$ dimensional lag operator in state m where L is the lag operator, so that $\mathbf{Y}_{t-p} = L^p\mathbf{Y}_t$. For stationarity, we assume that there are no roots on or inside the unit circle $|\mathbf{A}_m(z)| \neq 0$ for $|z| \leq 1$ and $m = 1, \ldots, M$. $S_t \in \{1, \ldots, M\}$ is the unobservable state variable that follows a discrete time, discrete state first-order irreducible ergodic Markov chain with the following transition probability matrix,

$$\{\Pr(S_t = i | S_{t-1} = j)\} = \{q_{ji}\} = \mathbf{Q} \tag{62}$$

Let $\mathcal{F}_{t-1}$ denote the σ-field generated by the lagged endogenous variables, i.e. $\mathcal{F}_{t-1} = \sigma(\mathbf{Y}'_{t-1}, \ldots, \mathbf{Y}'_1, \mathbf{Y}'_0, \ldots, \mathbf{Y}'_{1-p})$, then the probability distribution of $\mathbf{Y}_t$ conditional on the state variable and the information set at time $t-1$, $f(\mathbf{Y}_t | S_t = m, \mathcal{F}_{t-1})$, can be expressed as follows:

$$f(\mathbf{Y}_t | S_t = m, \mathcal{F}_{t-1}) = \log(2\pi)^{-1/2} \log|\mathbf{\Sigma}_m|^{-1/2} \exp((\mathbf{Y}_t - \overline{\mathbf{Y}}_{mt})'\mathbf{\Sigma}_m^{-1}(\mathbf{Y}_t - \overline{\mathbf{Y}}_{mt})) \tag{63}$$

where $\overline{\mathbf{Y}}_{mt} = E[\mathbf{Y}_t | S_t = m, \mathcal{F}_{t-1}]$ is the conditional expectation of $\mathbf{Y}_t$ in regime m. In other words, the conditional density of $\mathbf{Y}_t$ for a given state m, i.e. $S_t = m$, is a multivariate normal, i.e. $\mathbf{Y}_t \sim NID(\overline{\mathbf{Y}}_{mt}, \mathbf{\Sigma}_m)$. Collect these conditional probability distributions in an $(M \times 1)$ vector η_t:

$$\eta_t = \begin{pmatrix} f(\mathbf{Y}_t | S_t = 1, \mathcal{F}_{t-1}) \\ \vdots \\ f(\mathbf{Y}_t | S_t = M, \mathcal{F}_{t-1}) \end{pmatrix} \tag{64}$$

[16]One should note that the notation used in this section is independent of the notation used in the text.

Furthermore, let an $(M \times 1)$ vector $\xi_{t|t}$ denote the probability of the state variable, S_t, conditional on data obtained through date t, i.e.

$$\xi_{t|t} = \begin{pmatrix} \Pr(S_t = 1|\mathcal{F}_t) \\ \vdots \\ \Pr(S_t = M|\mathcal{F}_t) \end{pmatrix} \tag{65}$$

One could also imagine forming forecasts of how likely the process is to be in state m in period $t+1$ given observations through date t. Collect these forecasts in an $(M \times 1)$ vector $\xi_{t+1|t}$, which is a vector whose m^{th} element represents $\Pr(S_{t+1} = m|\mathcal{F}_t)$.

The optimal inference and forecast for each date t in the sample can be found by iterating on the following pair of equations:

$$\xi_{t|t} = \frac{(\xi_{t|t-1} \odot \eta_t)}{\mathbf{1}'(\xi_{t|t-1} \odot \eta_t)} \tag{66}$$

$$\xi_{t+1|t} = \mathbf{Q} \cdot \xi_{t|t} \tag{67}$$

where $\mathbf{1}$ represents an $(M \times 1)$ vector of 1s, and the symbol $\odot$ denotes element-by-element multiplication. Given a starting value $\xi_{1|0}$ and assumed values for the population parameters of the model, one can iterate Equations (66) and (67) for $t = 1, 2, \ldots, T$ to calculate the values of $\xi_{t|t}$ and $\xi_{t+1|t}$ for each date in the sample. One should note that the filtering algorithm discussed here is identical to investors' learning process. The log likelihood function $\mathcal{L}$ for the observed data in the information set, $\mathcal{F}_T$, can also be calculated as a by-product of this algorithm from

$$\mathcal{L} = \sum_{t=1}^{T} \log(\mathbf{1}'(\xi_{t|t-1} \odot \eta_t)) \tag{68}$$

Maximum likelihood (ML) estimation of the model is based on an implementation of the Expectation Maximization (EM) algorithm proposed by Hamilton (1989) for this class of models.