The Macroeconomic Announcement Premium*

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Abstract

Recent empirical evidence demonstrates a macroeconomic announcement effect: a large proportion of the equity premium is realized on scheduled macroeconomic announcement days, while the volatility remains unchanged. Moreover, market beta explains excess returns on announcement days, but not on days without announcements. This paper proposes a rare-event based explanation for these phenomena.

1 Introduction

Since the work of Sharpe (1964) and Lintner (1965), the capital asset pricing model (CAPM) has been the benchmark model for the cross-section of asset returns. While deviations from the CAPM have proliferated, the model remains the benchmark framework for understanding the relation between risk and return. Recently, Savor and Wilson (2014) document a striking fact about the fit of the CAPM. Though the CAPM does a poor job of explaining the overall relation between risk and return, it does very well on a subset of trading days, namely those days in which the Federal Reserve System or the Bureau of Labor Statistics releases macroeconomic news.

Figure 1 reproduces the main result of Savor and Wilson (2014) using updated data. We construct beta-sorted portfolios, and show the security market line, namely the graphical relation between expected return in excess of the Treasury bill and beta. On non-announcement days (the majority), the slope is very close to zero, and in fact is slightly negative. On announcement days, the slope is

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strongly positive and statistically significant. In addition, dots representing the portfolios seem to be well following the security market line, suggesting (partially) success of CAPM and contradicting the well-established view that CAPM should not be able to explain the mean excess returns in cross section.

One potential explanation for the findings of Savor and Wilson (2014), is that the risk is different on announcement and non-announcement days. However, covariances and variances can be measured very accurately, and it turns out that both risk measures are nearly indistinguishable on both sets of days. This deepens the puzzle, and, as Savor and Wilson discuss, rules out a host of possible risk-based explanations.

These cross-sectional findings are closely related to the finding that market returns are much higher on announcement days as opposed to non-announcement days. This finding is the focus of Savor and Wilson (2013) who show that it is so strong that the majority of the observed equity premium is realized on macroeconomic announcements. We can summarize the facts as follows:

1. The slope of the security market line is higher on announcement days than on non-announcement days. The difference is economically and statistically significant.

2. The security market line is essentially flat on non-announcement days.

3. The equity premium is much higher on announcement days as opposed to non-announcement days

4. Volatilities and betas with respect to the market are the same on both types of days.

We show that these findings can be explained in a model with rare economic disasters. The presence of rare events breaks the traditional relation between risk and return. This is key, because these findings together show a dramatic failure of the risk/return relation. We assume that the disaster probability has an observable and an unobservable component. We assume, for simplicity, that the unobserved component of the disaster probability follows a two-state Markov-switching process, and that macro-announcements fully reveal the state to investors. While these assumptions are stark, they simplify the analysis and serve to illuminate our main mechanism. Macro-announcement days feature a premium because news that strongly affects investors utility is revealed on these days. They do not feature higher observed volatility in samples where negative announcements, which are much less likely that positive announcements do not occur. We calibrate the model to postwar data and show that our model is able to reproduce main moments associated to the U.S. equity market while addressing the puzzles associated to macro-economic announcements raised above.

2 A model with announcement effects

2.1 Endowment and preferences

We assume an endowment economy with an infinitely-lived representative agent. Aggregate consumption (endowment) follows a geometric Brownian motion with constant drift. In addition, the consumption process is also associated to two (independent) rare events modeled as Poisson jumps:

$$\frac{dC_t}{C_{t^-}} = \bar{\mu}_C dt + \sigma dB_{C,t} + \left(e^{Z_{1,t}} - 1\right) dN_{1,t} + \left(e^{Z_{2,t}} - 1\right) dN_{2,t}, \tag{1}$$

where $N_{1,t}$ are $N_{2,t}$ two independent Poisson processes with jump intensity $\lambda_{1,t}$ and $\lambda_{2,t}$, respectively. $Z_{1,t}$ and $Z_{2,t}$ are two random variables with the same distribution, denoted by ν, and capture the actual size of rare disasters. (We assume that $Z_{1,t} < 0$ and $Z_{2,t} < 0$.) $B_{C,t}$ is a standard Brownian motion. All processes described above are assumed to be independent.

The Poisson processes N_{1t} and N_{2t} capture rare events. If no rare events occur, aggregate consumption drifts at a rate $\bar{\mu}_C$, and is hit by normal-times shocks dB_{Ct}. The rare events represent huge negative shock to consumption. This structure follows that of Wachter (2013). We discuss the intensity of the Poisson processes in what follows.

We assume the representative agent has recursive utility with EIS equal to 1, which gives us closed-form solutions up to ordinary differential equations.[1] We use the continuous-time characterization of Epstein and Zin (1989) derived by Duffie and Epstein (1992). The following recursion characterizes utility V_t:

$$V_t = \max E_t \int_t^{\infty} f(C_s, V_s) ds, \tag{2}$$

where

$$f(C_t, V_t) = \beta(1-\gamma)V_t \left(\log C_t - \frac{1}{1-\gamma}\log[(1-\gamma)V_t]\right). \tag{3}$$

Here β represents the rate of time preference, and γ represents relative risk aversion.

2.2 The jump intensity and scheduled announcements

The jump intensity, $\lambda_{1,t}$, can take two different values: $0 < \lambda^G < \lambda^B$. However, the value $\lambda_{1,t}$ is not directly observable to the market: agents can only rationally forecast the value of $\lambda_{1,t}$, conditioning on the information set at time t. We call λ^G the good state, and λ^B the bad.

Following Benzoni et al. (2011), we model the the dynamics of $\lambda_{1,t}$ by a continuous time regime

[1]Methods of Tsai and Wachter (2017) extend this solution to an approximate analytical solution with non-unitary EIS.

switch model. The model is characterized by

$$\begin{aligned} P(\lambda_{1,t+\Delta t} = \lambda^G | \lambda_{1,t} = \lambda^B) = \phi_{BG} dt \\ P(\lambda_{1,t+\Delta t} = \lambda^B | \lambda_{1,t} = \lambda^G) = \phi_{GB} dt. \end{aligned} \tag{4}$$

We assume, as in the data, that announcements occur periodically, and let T be the period length. [2] We assume that macro-economic announcements convey news about future disasters by fully revealing the value of $\lambda_{1,t}$.[3] While disasters can take place at any time, the bad state, with which $\lambda_{1,t} = \lambda^B$ is particularly concerning for agents as it implies a large possibility of disasters. The update of $\lambda_{2,t}$ then becomes a huge source of risk for agents.

The process of $\lambda_{2,t}$, however, follows a Cox-Ingersoll-Ross process (Cox et al. (1985)), and is perfectly observable to agents:

$$d\lambda_{2,t} = -\kappa(\lambda_{2,t} - \bar{\lambda}_2)dt + \sigma_\lambda \sqrt{\lambda_{2,t}} dB_{\lambda,t}. \tag{5}$$

We assume, for simplicity, that $B_{\lambda,t}$ is independent of B_{Ct}.

These assumptions imply that an announcement is itself perfectly anticipated. However, the transition between the good and bad states can only be revealed on announcements, and thus associate the announcements with uncertainty.

2.3 The state-price density

We start by characterizing the state-price density, which will determine prices and returns on a cross-section of firms. First, group the Brownian motions together into a vector:

$$dB_t = [dB_{C,t}, dB_{\lambda,t}]^\top.$$

Then we define

$$\tau = t \bmod T,$$

or the time passed since the most recent announcement.

We define several additional state variables to incorporate the agents' rational belief about the

[2]Scheduled announcements are not perfectly evenly distributed in the data. This simplification keeps the model tractable and allows us to focus on the main mechanism.

[3]We assume that the U.S. government has a greater information set than the overall economy. We do not model the micro-foundations of information collection. See Stein and Sunderam (2015) for a model of why announcements convey more information than they might seem.

good and bad states and other relevant information

$$p_t = \Pr(\lambda_{1,t} = \lambda^B | \mathcal{F}_t).$$

where $\mathcal{F}_t$ is defined as the information set of the agents at time t. So here p_t can be understood as the belief in the probability of bad state at time t. We further define

$$\bar{\lambda}(p_t) = p_t \lambda^B + (1 - p_t)\lambda^G, \tag{6}$$

which can be understood as the *posterior* jump intensity of $N_{1,t}$, given the belief in the bad state p_t.

Finally, we define

$$p_0(t) = p_{s(t)},$$

where

$$s(t) = \max\{s : s \leq t \text{ and } s \bmod T = 0\}.$$

Here $p_0(t)$ stands for the information about the revealed state after the most recent announcement. Obviously $p_0(t)$ can only take value 0 or 1.

The following theorem characterizes the state-price density π_t.

Theorem 1. *For $\tau \in (0, T)$, or between announcements, the following equation characterizes the dynamics of the unique state-price density π_t:*

$$\begin{aligned}\frac{d\pi_t}{\pi_{t-}} = -r_t dt - \bar{\lambda}(p) E_\nu \left[e^{-\gamma Z_{1,t}} - 1\right] dt - \lambda_{2,t} E_\nu \left[e^{-\gamma Z_{2,t}} - 1\right] dt \\ + \sigma_{\pi,t}^\top dB_t + [e^{-\gamma Z_{1,t}} - 1] dN_{1,t} + [e^{-\gamma Z_{2,t}} - 1] dN_{2,t},\end{aligned} \tag{7}$$

where

$$\sigma_{\pi,t} = \left[-\gamma\sigma, (1-\gamma) b_\lambda \sigma_\lambda \sqrt{\lambda_{2,t}}\right]^\top \tag{8}$$

$$b_p = \frac{(\lambda^B - \lambda^G)\left[E_\nu e^{(1-\gamma)Z_{1,t}} - 1\right]}{(1-\gamma)(\beta + \phi_{GB} + \phi_{BG})}. \tag{9}$$

$$b_\lambda = \frac{1}{(1-\gamma)\sigma_\lambda^2}\left(\beta + \kappa - \sqrt{(\beta+\kappa)^2 - 2\sigma_\lambda^2 [E_\nu e^{(1-\gamma)Z_{2,t}} - 1]}\right), \tag{10}$$

and r_t is the riskfree rate, given by

$$r_t = \beta + \bar{\mu}_C - \gamma\sigma^2 + \bar{\lambda}(p_t) E_\nu \left[e^{-\gamma Z_{1,t}}(e^{Z_{1,t}} - 1)\right] + \lambda_{2,t} E_\nu \left[e^{-\gamma Z_{2,t}}(e^{Z_{2,t}} - 1)\right]. \tag{11}$$

For $\tau = 0$, or upon announcements, the following equation characterizes π_t:

$$\frac{\pi_t}{\pi_{t^-}} = \frac{e^{(1-\gamma)(a(0;p_0(t))+b_p p_t)}}{e^{(1-\gamma)(a(T^-;p_0(t^-))+b_p p_{t^-})}}, \tag{12}$$

where

$$a(\tau; p_0(t)) = \zeta_{p_0(t)} e^{\beta\tau} + \frac{1}{\beta}\left(\mu - \frac{1}{2}\gamma\sigma^2 + b_p\phi_{GB} + b_\lambda \kappa\bar{\lambda} + \frac{\lambda^G}{1-\gamma}\left[E_\nu e^{(1-\gamma)Z_{1,t}} - 1\right]\right). \tag{13}$$

ζ_0 and ζ_1 are the solution to the following system of equations:

$$\begin{aligned} e^{(1-\gamma)\left(\zeta_0 e^{\beta T} + b_p p^G\right)} &= p^G e^{(1-\gamma)(\zeta_1 + b_p)} + (1-p^G)e^{(1-\gamma)\zeta_0} \\ e^{(1-\gamma)\left(\zeta_1 e^{\beta T} + b_p p^B\right)} &= p^B e^{(1-\gamma)(\zeta_1 + b_p)} + (1-p^B)e^{(1-\gamma)\zeta_0}, \end{aligned} \tag{14}$$

where the function $p^G = p(T^-; 0)$, $p^G = p(T^-; 1)$, and $p(\tau; p_0)$ is defined as

$$p(\tau; p_0) = \left(p_0 - \frac{\phi_{GB}}{\phi_{GB} + \phi_{BG}}\right) e^{-(\phi_{BG}+\phi_{GB})\tau} + \frac{\phi_{GB}}{\phi_{GB} + \phi_{BG}}.$$

Proof. See Appendix A. □

Recall that the state-price density can be informally viewed as the marginal utility process for the representative investor (Appendix A makes this intuition precise). The term $-\gamma\sigma$ captures the CCAPM affect, negligible in our calibration. The terms multiplying $dN_{j,t}$ reflect the change in marginal utility in the two types of disasters. Because these affect consumption directly, they always appear. When $\gamma > 0$, the agent is risk averse, and marginal utility rises when a disaster takes place. Moreover, when $\gamma > (\text{EIS})^{-1} \equiv 1$, or the agent prefers an early resolution of uncertainty, $b_\lambda < 0$, from (7) it follows that marginal utility rises when the probability of disaster rises if and only if $\gamma > 1$.

However, p_t only shows up by affecting the risk-free rate and the disaster premium, as described by Tsai and Wachter (2016), while the marginal utility of agent does not change by baring the variation in p_t otherwise. The intuition is that the path of p_t is deterministic between announcements, and as a result p_t should not be a priced risk.

Note what does not appear in (7), namely, a term accounting for the effect of announcement periods on state prices. It might seem like these riskier periods would lead to higher prices of risk.[4]

Note also that τ only appear in (7) through affecting p_t. It seems that by approaching announcements, the economy is facing a growing uncertainty about the perspective and would charge a higher

[4]Indeed, a positive shock to marginal utility due to a disaster is more likely during the announcement period. To compensate, the average marginal utility is lower, which we see from the drift in (7).

price of risk. However, when the EIS is equal to 1, the announcements only shift the future consumption without affecting consumption today (the income and substitution effects cancel out). So only risk-free rate and disaster premium are affected.

Between announcements, the term p_t only affects the dynamics of the state price density by determining the *posterior* probability of type 1 disasters, while p_t itself does not show up as a stochastic term. The reason is that given the most recent revealed state, there is no additional information about p_t and as a result the dynamics of p_t becomes deterministic. As a result the agent should be able to fully understand this and adjust accordingly.

The following corollary characterizes the state price density upon announcements.

Corollary 2.1. *The following inequality holds*

$$\zeta_0 > \zeta_1 + b_p, \tag{15}$$

where $\gamma > 1$.

Proof. See Appendix A.3.1. □

Corollary 2.1 implies that the value function of the representative agent will increase if the revealed state after announcement. Note that $1 - \gamma < 0$, we then can see that the state price density will decrease when the state is revealed to be good, and people's marginal utility goes down.

2.4 Equity prices

We consider a cross-section of firms with which differ in their sensitivity to disasters. We will evaluate the CAPM on announcement and non-announcement days using data simulated from these firms. As in the data, the market portfolio return will be the return on a value-weighted portfolio of the underlying firms.

For $k = 1, \ldots, K$, let D_t^k equal the dividend stream of firm k. Assume

$$\frac{dD_t^k}{D_t^k} = \bar{\mu}_D dt + \sigma dB_{C,t} + (e^{\phi_k Z_{1,t}} - 1)dN_{1,t} + (e^{\phi_k Z_{2,t}} - 1)dN_{2,t}, \tag{16}$$

where ϕ_k is the loading on disasters. We assume that firms have the same loading on the Brownian shock dB_{Ct}. This is in part for simplicity. It also has the attractive property that, absent rare events, dividend shares and market weights are stationary, implying that no one firm takes over the economy.[5]

[5] Given that we simulate for a finite length of time, a non-stationary distribution of relative firm values is not necessarily a problem. However, because it affects measured CAPM betas, the resulting simulated moments are noisier and harder to interpret.

See Kilic and Wachter (2017) for a production-based model that micro-founds values of $\phi_k > 1$.

We solve for the value of an asset with dividend stream given by (16). In addition to the state variables defined in the previous section, we further define

$$\tau = t \bmod T. \tag{17}$$

Here τ equals the time elapsed since end of the most recent announcement period. The following theorem characterizes the price of the assets with the dividend process given above:

Theorem 2. *The time-t price of asset k with dividend stream (16) takes the form*

$$F_\phi^k\big(D_t^k, p_t, p_0(t), \lambda_{2,t}, \tau, s\big) = D_t^k G_\phi^k\big(p_t, p_0(t), \lambda_{2,t}, \tau\big), \tag{18}$$

where

$$G_\phi^k\big(p_t, p_0(t), \lambda_{2,t}, \tau\big) = \int_0^\infty \exp\left\{a_\phi^k\big(\tau, s; p_0(t)\big) + b_{\phi,p}^k(s)p_t + b_{\phi,\lambda}^k(s)\lambda_{2,t}\right\} ds, \tag{19}$$

is the price-dividend ratio, and

$$b_{\phi,p}^k(s) = \frac{(\lambda^B - \lambda^G)E_\nu\left[e^{(\phi_k-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}}\right]}{\phi_{BG}+\phi_{GB}}\left(1 - e^{-(\phi_{BG}+\phi_{GB})s}\right). \tag{20}$$

The function $b_{\phi,\lambda}^k(s)$ solves the ODE

$$\frac{db_{\phi,\lambda}^k(s)}{ds} = \frac{1}{2}\sigma_\lambda^2 b_{\phi,\lambda}^k(s)^2 + \left[(1-\gamma)b_\lambda\sigma_\lambda^2 - \kappa\right] b_{\phi,\lambda}^k(s) + E_\nu\left[e^{(\phi_k-\gamma)Z_{2,t}} - e^{(1-\gamma)Z_{2,t}}\right], \tag{21}$$

with boundary condition

$$b_{\phi,\lambda}(0) = 0.$$

$a_\phi\big(\tau, s; p_0(t)\big)$ *is given by*

$$a_\phi\big(\tau, s; p_0(t)\big) = h\big(n, \tau, s; p_0(t)\big) + \int_0^s \left(-\beta - \mu + \bar{\mu}_D + \lambda^G E_\nu\left[e^{(\phi_k-\gamma)Z_t} - e^{(1-\gamma)Z_t}\right] + \kappa\bar{\lambda}b_{\phi,\lambda}^k(u)\right) du, \tag{22}$$

where $n = \left[\frac{\tau+s}{T}\right]$ is the number of announcements before the maturity, and $h\big(n, \tau, s; p_0(t)\big)$ is defined recursively by

1. $h(0, \tau, s; 0) = h(0, \tau, s; 1) = 0$;

2. *For $k = 1, 2, 3, \ldots, n$*

$$
\begin{aligned}
h(k,\tau,s;0) = \log \Big\{ & p^G \exp^{(1-\gamma)(a(0;1)+b_p)+h(k-1,\tau,s;1)+b_{\phi,p}\left(s^*+(k-1)T\right)} \\
& + (1-p^G)\exp^{(1-\gamma)a(0;0)+h(k-1,\tau,s;0)} \Big\} \\
& \quad - b_{\phi,p}\big(s^* + (k-1)T\big)p^G - (1-\gamma)b_p p^G - (1-\gamma)a(T^-;0) \\
h(k,\tau,s;1) = \log \Big\{ & p^B \exp^{(1-\gamma)(a(0;1)+b_p)+h(k-1,\tau,s;1)+b_{\phi,p}\left(s^*+(k-1)T\right)} \\
& + (1-p^B)\exp^{+b_p a(0;0)+h(k-1,\tau,s;0)} \Big\} \\
& \quad - b_{\phi,p}\big(s^* + (k-1)T\big)p^B - (1-\gamma)b_p p^B - (1-\gamma)a(T^-;1)
\end{aligned} \tag{23}
$$

where $s^* = (\tau + s) \bmod T$; $p^G = p(T^-;0)$, $p^B = p(T^-;1)$ are the probability of bad state right before the announcement, given that the most recent announcement revealed a good (bad) state.

Proof. See Appendix B. □

Thus the term $D_t^k \exp\left\{a_\phi^k\big(\tau, s; p_0(t)\big) + b_{\phi,p}^k(s)p_t + b_{\phi,\lambda}^k(s)\lambda_{2,t}\right\}$ is the price today of a dividend paid s periods in the future. Each of the terms in this exponential has an economic interpretation which we give below.

The terms $b_{\phi,p}^k(s)$, is the responses of prices to the change in p_t, or the *posterior* probability of bad state. Because $\lambda_{1,t}$, is market-wide cash flow variables, it affects future riskfree rates (11) and disaster premium (7), and thus the price response reflects a tradeoff among a cash flow, a risk premium and a risk-free rate effect. Equation 20 shows that $b_{\phi,p}^k(s) < 0$ if and only if $\phi_k > 1$. That is, when $\phi_k > 1$ (recall that 1 is the EIS of the representative agent) the joint effect of cash flow and risk premium dominates, and the prices is an decreasing function of p_t. $b_{\phi,\lambda}^k(s)$ also reflects the impact of the distribution of cash flows. Namely, $b_{\phi,\lambda}^k(s)$ reflect the response of prices to to a change in $\tilde{\lambda}_t$. When $\phi_k > 1$, the price is a decreasing function of $\lambda_{2,t}$ because higher $\lambda_{2,t}$ implies that future consumption and cash flow become riskier. We can see the role of both of these forces in the last term in the ODE (21). If this last term were zero, then $b_{\phi,\lambda}^k(s) = 0$ for all s.

To summarize, provided that ϕ_k is greater than 1, asset prices fall upon the realization of a disaster $dN_{2,t} = 1$ and $dN_{2,t} = 1$. Asset prices also fall upon an unpredictable increase in the probability of a disaster $dB_{\lambda t} > 0$.

2.4.1 Risk premium during non-announcement periods

This section describes risk premium on the equities whose prices we computed in Section 2.4. The formulas we derive show that the model can qualitatively match the facts we describe in the introduction.

Again, we start with characterizing the premium during non-announcement periods, and then focus on the premium associated to announcements.

To simplify the notation, let $F_t^k = F^k\big(D_t^k, p_t, p_0(t), \lambda_{2,t}, \tau\big)$, $G_t^k = G_\phi^k\big(p_t, p_0(t), \lambda_{2,t}, \tau\big)$ When $\tau \in (0, T)$, locally, there exist processes $\mu_{F,t}^k$ and $\sigma_{F,t}^k$ such that

$$\frac{dF_t^k}{F_t^k} = \mu_{F,t}^k dt + \sigma_{F,t}^k dB_t + \frac{\mathcal{J}_1(F_t^k)}{F_{t^-}^k} dN_{1,t} + \frac{\mathcal{J}_2(F_t^k)}{F_{t^-}^k} dN_{2,t}, \tag{24}$$

where $\mathcal{J}_j(\cdot)$ is the operator for the change of a process conditioning on a Poisson arrival of type j rare event.

The instantaneous expected excess return of the asset is then given by

$$r_t^k - r_t = \mu_{F,t}^k + \bar{\lambda}(p_t) E_{\nu_1}\left[\frac{\mathcal{J}_1(F_t^k)}{F_{t^-}^k}\right] + \lambda_{2,t} E_{\nu_2}\left[\frac{\mathcal{J}_2(F_t^k)}{F_{t^-}^k}\right] + \frac{D_t^k}{F_t^k} - r_t. \tag{25}$$

The following theorem characterizes the instantaneous expected excess return, or the premium, of the asset during non-announcement periods:

Theorem 3. *While $\tau \in (0, T)$, or during the announcement period, the instantaneous risk premium for an equity asset defined in section 2.4 is given by*

$$\begin{aligned} r_t^k - r_t = \gamma\sigma^2 - \lambda_{2,t}(1-\gamma)\frac{1}{G_t^k}\frac{\partial G_t^k}{\partial \lambda_t} b_\lambda \sigma_\lambda^2 \\ - \bar{\lambda}(p_t) E_\nu\left[\left(e^{-\gamma Z_{1,t}} - 1\right)\left(e^{\phi_k Z_{1,t}} - 1\right)\right] \\ - \lambda_{2,t} E_\nu\left[\left(e^{-\gamma Z_{2,t}} - 1\right)\left(e^{\phi_k Z_{2,t}} - 1\right)\right]. \end{aligned} \tag{26}$$

The theorem divides the premium into four components: the first is the standard consumption CAPM term. The second term is the premium the investors require for baring the risk of facing the time-varying probability of type 2 disasters. The third term is the premium directly linked to the type 1 rare disasters: the jump intensity the agent uses is the posterior intensity given by the best information available; the fourth term stands for the premium demanded for baring the type 2 disaster.

The following corollary characterizes all terms in Equation 26.

Corollary 2.2. *1. For $\phi_k > 0$, $j = 1, 2$, the premiums for both type 1 and type 2 are positive.*

2. The premium for the time-varying probability of disaster is positive if and only if $\phi_k > 1$.

Proof. The first part is given by the fact that $\gamma > 0$, and $\phi_k > 0$.

The second part is given by the fact $\partial G_t^k/\partial\lambda_t < 0$ if and only if $\phi_k > 1$. This can be proved by the fact that $b^k_{\phi,\lambda}(s) < 0, \forall s > 0$, with $b^k_{\phi,\lambda}(0) = 0$ when $\phi_k > 1$. □

2.5 The announcement premium

In this section, we focus on characterizing the announcement premium. Specifically, we define the announcement premium as the expect return upon realization of the announcements, given the information right before. Since there is no time needed for the realization of the shocks, excess return equals to return for announcements premium.

The following theorem gives a characterization of the announcement premium.

Theorem 4. *Upon announcements, or when $t \bmod T = 0$, the announcement premium for F_t^k, defined as*

$$E\left[\frac{F_\phi^k(D_t^k, p_t, p_0(t), \lambda_{2,t}, 0)}{F_\phi^k(D_{t^-}^k, p_{t^-}, p_0(t^-), \lambda_{2,t^-}, T^-)}\Big|\mathcal{F}_{t^-}\right], \tag{27}$$

is positive when $\phi_k > 1$.

Proof. See Appendix B.5 □

When the $\lambda_{1,t}$ is revealed to be λ^G, with $\phi_k > 1$, the asset price will increase. Note that Corollary 2.2 implies that λ^G is good news for the agents. This implies that agents are baring risk by taking positive position of the assets before announcements, and then the agents will charge a positive premium.

2.5.1 The observed premium without rare events

The premium takes into account the case in which the rare events actually take place. However, if we assume that 1) rare events is absent 2) The regime remains good all the time, the premium the market observes is actually given by the following corollary.

Corollary 2.3. *When $\tau \in (0, T)$, the observed instantaneous risk-premium for an equity asset defined in section 2.4, conditional on that the rare event does not take place, is given by*

$$\begin{aligned} r_t^k - r_t = \gamma\sigma^2 - \lambda_{2,t}(1-\gamma)\frac{1}{G_t^k}\frac{\partial G_t^k}{\partial \lambda_t} b_\lambda \sigma_\lambda^2 \\ - \bar{\lambda}(p_t) E_\nu\left[e^{-\gamma Z_{1,t}}\left(e^{\phi_k Z_{1,t}} - 1\right)\right] \\ - \lambda_{2,t} E_\nu\left[e^{-\gamma Z_{2,t}}\left(e^{\phi_k Z_{2,t}} - 1\right)\right]. \end{aligned} \tag{28}$$

When $\tau = 0$, or upon announcements, the observed announcement premium for an equity asset, conditional on that the regime remains good all the time, is given by

$$\frac{G_\phi^k(0, 0, \lambda_{2,t}, 0)}{G_\phi^k(p^G, 0, \lambda_{2,t}, T^-)} - 1. \tag{29}$$

On important feature is that, for any zero-coupon dividend claim, the observed announcement return is constant, given that the regime remains good. Let $H_\phi^k(p_t, p_0(t), \lambda_{2,t}, \tau, s)$ be the time t price of D_{t+s}. Then we have

$$H_\phi^k(p_t, p_0(t), \lambda_{2,t}, \tau, s) = D_t \exp\left\{a_\phi^k\big(\tau, s; p_0(t)\big) + b_{\phi,p}^k(s)p_t + b_{\phi,\lambda}^k(s)\lambda_{2,t}\right\}. \tag{30}$$

Then upon announcements, given that the most recent revealed and announced states are both good, the observed announcement premium for H_ϕ^k is given by

$$\begin{aligned}
&\frac{H_\phi^k(0, 0, \lambda_{2,t}, 0, s)}{H_\phi^k(p_G, 0, \lambda_{2,t^-}, T^-, s^+)} - 1 \\
=&\frac{\exp\left\{a_\phi^k\big(0, s; 0\big) + b_{\phi,p}^k(s) \times 0 + b_{\phi,\lambda}^k(s)\lambda_{2,t}\right\}}{\exp\left\{a_\phi^k\big(T^-, s^+; 0\big) + b_{\phi,p}^k(s^+)p^G + b_{\phi,\lambda}^k(s^+)\lambda_{2,t^-}\right\}} - 1 \\
=&\frac{\exp\left\{a_\phi^k\big(0, s; 0\big)\right\}}{\exp\left\{a_\phi^k\big(T^-, s^+; 0\big) + b_{\phi,p}^k(s^+)p^G\right\}} - 1,
\end{aligned} \tag{31}$$

which is only a function of s and obviously positive. This implies that there will be no volatility observed in the sample for the announcement premium of zero-coupon dividend assets. As a result, the announcement premium for the equity claim, which is a weighted average of (31), will also be observed to be almost constant with zero volatility (as the weights depend on the stochastic state variable, $\lambda_{2,t}$.

This helps us to address the puzzle raised above. On any given trading day, the assets will bare a volatility which is captured by the variation driven by $dB_{C,t}$ and $dB_{\lambda,t}$, and the market charges the premium associated. In addition, the market also charges the premium associated to the disaster risk.

However, on announcement days, the market in fact bares the risk associated to the state to be revealed. But we might not be able to observe the variation associated as the change of regime is very rare and we then can only see the price the market is charging for baring it on good days.

3 Quantitative results

In this section, we start with showing the empirical evidence of macro-economic announcement effects documented by Savor and Wilson (2014) with extended samples. After that we proceed to simulations and show that the effects can be produced with our model.

To avoid confusion with notations, we use capitalized letters to denote realization of random variables. For example, we use $RX_{t,t+\Delta t}$ to denote the realization of excess return for the period from t to $t + \Delta t$. We also use hats to denote the empirical estimates of variables. For example, we use $\hat{E}(RX_{t,t+\Delta t})$ to denote the estimated unconditional mean excess return, or the estimated unconditional premium.

As we simulate daily returns, it is easier to distinguish sample days with and without announcements. To be specific, we let $\mathcal{A}$ and $\mathcal{N}$ be the sets of announcement and non-announcement days, respectively.

3.1 Empirics

3.1.1 Data and methodology

We obtain daily stock returns from the Center for Research in Security Prices (CRSP) for all the individual stocks traded on NYSE, AMEX, NASDAQ and ARCA from Jan 1961 to Sept 2016. We use the daily excess returns of Fama-French 25 portfolios and industry portfolios provided by Kenneth French. In addition, we also use the daily market excess returns and risk-free rate provided by Kenneth French.

The scheduled announcement dates before 2014 are provided by Savor and Wilson (2014). We manually add the dates of the Federal Open Market Committee target rate, Bureau of Labor Statistics inflation and employment announcements after 2014 to the data set following the approach by Savor and Wilson (2014).

We define the excess daily returns (level) as the daily return of an asset in excess of the risk-free rate given by Kenneth French, and log excess return as the difference between the log daily return and log risk free rate.

3.1.2 Beta-sorted portfolios

Following Savor and Wilson (2014), we start with constructing 10 beta-sorted portfolios with US equity data. The beta-sorted portfolios are portfolios constructed according to one stock's CAPM market beta.

We consider all stocks traded on NYSE, AMEX, NASDAQ and ARCA from Jan 1961 to Sept 2016. The portfolio compositions are updated monthly. At the end of each trading month, individual stock's market betas are estimated using daily excess returns with a 12-month rolling window. To ensure the accuracy of estimates, we only include stocks which are available for trading on more than 90% of the trading days in the sample for beta estimation.

After finishing estimating the betas, we compute the 10 quantiles of the stock betas, and then assign individual stocks to 10 different portfolios accordingly. The portfolio returns are value-weight averages of the individual stocks. As a result, we obtain the time-series of the daily excess returns of 10 beta-sorted portfolios.

3.1.3 Excess return v.s. CAPM beta on announcement and non-announcement days

The main message of the empirical analysis is delivered in Figure 1 and Table 1.

We compute the mean excess returns of the ten beta-sorted portfolios on announcement and non-announcement days, respectively. In addition, we use the market excess returns and compute the corresponding CAPM beta of the portfolios on those two type of days.

We can see that the CAPM beta estimated on announcement days and non-announcement days are nearly identical for each portfolio. The volatility, measured by standard deviation of excess returns, also remains nearly identical.

We can also see the announcement premium described by Savor and Wilson (2014). The security market line of the portfolios on announcement days seem to be associated to a much higher slope than that on non-announcement days. In addition, it appears that the market beta is capable of explaining the cross-sectional variation in mean excess returns on announcement days, as the risk premium realized on announcement days appears to be proportional to the CAPM beta.

3.2 Simulation

In this part, we focus on evaluating the performance of our model through simulation.

We start with calibrating the aggregate economy with multiple equity assets (or portfolios). The parameters are mainly from Wachter (2013). In our simulation, there are 240 trading days per year, and one announcement day every ten trading days. This specification can reflect the fact that there are approximately 2 macro-economy announcements in each calendar month, while keeps the simplicity of simulation.

We choose $\bar{\lambda}$, ϕ_{GB}, ϕ_{BG}, λ^B and λ^G such that the the unconditional jump intensity for the two Poisson processes together is 3.55% per annum, a number which we take from the work of Wachter

(2013) and Barro and Ursúa (2008). In addition, we employ the samples of rare consumption decline from Barro and Ursúa (2008), and assume that the distribution is multinominal in out model. ϕ_{GB} implies that on average it takes 20 years for an economy in good state to switch to a bad one, while ϕ_{BG} implies a average length of 3 years in bad state. For simplicity, we let $\lambda^G = 0$. The bad state can then be understood as a period with much higher chance of diasters.

The details of parameter choice are reported in Table 2.

In our simulation, we have 12 firms (portfolios) with different leverage levels ϕ_k, and set the announcement at the *middle* of the announcement days. This allows us to quickly compute the daily returns of the assets by facilitating end-of-day prices while avoiding the prices right before and after announcements.

We run 500 parallel simulation samples. Each sample runs 100 years (or 240×100 periods). We drop the first 50 years of observations in order to obtain a stationary distribution of the state variables at the beginning of each sample. In addition, we focus on samples that always remain in the good state and without disaster realization in the second half. This is obtained by re-sampling the sample path of state variables (state, rare events, etc) until we obtain a path that meets our criteria. In fact, by such sampling strategy we can obtain a stationary distribution of state variables at the beginning of samples, conditioning on that there is no rare events.

3.2.1 Simulated moments

For each simulation sample, with the simulated state variables, we then can employ (18) and obtain a time series of asset prices $\{F_t^k\}_t$. Then we use the following approximation to compute the time series of daily returns of assets.

$$\begin{aligned} R^k_{t,t+\Delta t} &\approx \frac{F^k_{t+\Delta t} + D^k_{t+\Delta t}\Delta t}{F^k_t} \\ &= \frac{D^k_{t+\Delta t}G^k_{t+\Delta t} + D^k_{t+\Delta t}\Delta t}{D^k_t G^k_t} \\ &= \frac{D^k_{t+\Delta t}}{D^k_t}\frac{G^k_{t+\Delta t} + \Delta t}{G^k_t} \\ &\approx \exp\left\{\bar{\mu}_D\Delta t - 0.5\sigma^2\Delta t + \sigma(B_{C,t+\Delta t} - B_{C,t})\right\}\frac{G^k_{t+\Delta t} + \Delta t}{G^k_t}, \end{aligned} \tag{32}$$

where $\Delta t = 1/240$.

The risk free rate is approximated by

$$R^f_t = \exp(r_t \Delta t). \tag{33}$$

The daily excess return of asset k is then

$$RX^k_{t,t+\Delta t} = R^k_{t,t+\Delta t} - R^f_t. \tag{34}$$

In addition, the log excess return of asset k is defined as

$$\log(1 + R^k_{t,t+\Delta t}) - \log(1 + R^f_t) = \log(1 + R^k_{t,t+\Delta t}) - r_t \Delta t.$$

For each simulation sample, we use the value-weighted average of the portfolios excess returns as the market. Specifically, we enforce that all assets have same values at the beginning of the second half of each sample, (as we only keep the second half for statistics calculation), and then let the values vary with state variables. We then can use the excess returns on announcement and non-announcement days to compute portfolio CAPM beta on those two types of days, respectively. In addition, we compute the mean excess returns of the portfolios on the two types of days.

The main feature we want to show with respect to our model can be summarized in Table 3, 4 and 5.

The medians of the simulated mean excess returns, volatilities and betas for the 12 beta-sorted portfolios on announcement and non-announcement days across simulation samples are reported in Table 4. The median volatilities and beta on two types of days are nearly identical in the simulation samples, while there is a spread between the mean excess returns on announcement and non-announcement days. The reason is that the time-varying probability of type 2 disasters is the main driver of volatilities attach to the assets as well as the aggregate market[6], and as a result moments associated to volatility, including volatility and beta, are unaffected on announcement days. However the announcements are associated with a premium, and on sample paths where there is no regime switch, the volatility associated can not be observed. As a result in statistics it appears that the premium is not associated with a higher level of risk.

Figure 3 delivers the boxplots of distribution of the mean excess returns on announcement and non-announcement days across simulation samples. We remove the outliers detected by the boxplots for the sake of clarity.

In addition, the simulation result for mean excess returns essentially captures the fact that CAPM beta is able to explain the cross-sectional variation in portfolio mean excess returns on announcement days. The reason is that the assets have the same loading on the two types of disasters.

We then turn to the Fama-MacBeth type regressions utilized by Savor and Wilson (2014). In fact, we run the following cross-sectional regressions

[6]See Wachter (2013).

$$\hat{E}(RX_t^k \mid t \in i) = \delta_i \beta_i^k + \eta_i^k, \tag{35}$$

where $i = \mathcal{A}$ or $\mathcal{N}$. With the simulation moments, we can easily build the 90% confidence interval under our model. The results are reported in Table 3. The 90% confidence interval constructed can well cover the empirical results, and suggest that the spread between the announcement and non-announcement day security market line slopes is significant.

Table 5 delivers similar message on the portfolio level: for each simulated portfolio, the difference in mean excess returns on the two types of trading days is significant, and appear to be proportional to the CAPM beta.

In addition, we also compute the summary statistics of the market portfolio, and the results are shown in Table 6. The important feature here is that the volatility of the market portfolio is the same on two different type of days, while the mean excess returns appear to be quite different.

3.2.2 Variance Ratio

We calculate the quarterly variance ratios of the portfolios on announcement and non-announcement day returns, similarly to the work done by Savor and Wilson (2014).

Specifically, for each calendar quarter, we compute the sum of the log daily excess returns on announcement and non-announcement days, respectively, and obtain the quarterly log announcement and non-announcement day returns. The quarterly returns are then used to compute cumulative of multiple quarters and then the variance ratios.

The results are reported in Table 7 and Figure 4.

One key fact of our computation here is that we compute the variances using sample variances, instead of the average squared returns. As pointed out by Barndorff-Nielsen and Shephard (2002), we need the sample path of returns to be continuous in order to correctly obtain the volatility using the squared return. However, in this case this condition does not hold as the model implies a jump in prices after announcements.

For reference, we also plot the variance ratios if we use mean squared return to estimate the unconditional variance. It is straightforward to see that the 90% confidence interval gets much wider, and the variance ratio does not move back to 1 at horizon of 20 quarters.

In fact this is again consistent with the fact that the premium on announcement days are much larger than on non-announcement days. To better understand the reason, consider a simplified model where the returns are $i.i.d.$ Let $r_{t,t+l}$ be the log return over a period with length l starting at time t.

We have mean squared return that follows

$$E(r^2_{t,t+l}) = var(r_{t,t+l}) + E(r_{t,t+l})^2. \tag{36}$$

As l grows, $var(r_{t,t+l})$ grows at rate l while $E(r_{t,t+l})^2$ grows at rate l^2. Then as $l \to \infty$, the $E(r_{t,t+l})^2$ term dominates and the variance ratio statistics, computed by

$$VR = \frac{\hat{r}^2_{t,t+l}}{l \times \hat{r}^2_{t,t+1}}, \tag{37}$$

will grow at a rate of l. The effect will be particularly large at smaller l's if $E(r_{t,1})$ is fairly large, which is the case in our analysis on announcement days.

Appendices

A Solving the representative agent's value function

To begin, we define

$$p_t = \Pr\left(\lambda_{1,t} = \lambda^B \middle| \mathcal{F}_t\right) \tag{A.1}$$

$$\tau = t \bmod T \tag{A.2}$$

$$p_0(t) = p_{s(t)}, \tag{A.3}$$

where

$$s(t) = \max\{s : s \leq t \text{ and } t \bmod T = 0\}. \tag{A.4}$$

Let $\mathcal{J}_j(f)$ be the change in a random variable or function f associated to type-j Poisson arrival, and $\bar{\mathcal{J}}_j(f)$ be its expectation with respect to the distribution ν.

A.1 The dynamics of p_t

We start with solving the probability of bad state based on the agent's information set.

When $\tau \in (0, T)$, or when the economy is in a non-announcement periods, for each dt, a measure of $(1-p_t)\phi_{GB}dt$ will become bad state; in addition, a measure of $p_t\phi_{BG}dt$ will become good state. This leads to a change of $[-p_t\phi_{BG} + (1-p_t)\phi_{GB}]dt$, and the following dynamics of p_t:

$$dp_t = \left[-p_t\phi_{BG} + (1-p_t)\phi_{GB}\right]dt = \left[-p_t(\phi_{GB}+\phi_{BG}) + \phi_{GB}\right]dt. \tag{A.5}$$

This implies that the dynamics of p_t is in fact non-stochastic between two neighboring announcements:

$$p_t = De^{-(\phi_{BG}+\phi_{GB})t} + \frac{\phi_{GB}}{\phi_{GB}+\phi_{BG}}, \tag{A.6}$$

where D is some un-determined constant.

Upon announcements, the value of $\lambda_{1,t}$ is fully revealed, and p_t can only take values 0 or 1. This implies that p_t in fact is a function of τ and $p_0(t)$. We call this $p\big(\tau; p_0(t)\big)$, and then obtain

$$p\big(\tau; p_0(t)\big) = \left(p_0(t) - \frac{\phi_{GB}}{\phi_{GB}+\phi_{BG}}\right)e^{-(\phi_{GB}+\phi_{BG})\tau} + \frac{\phi_{GB}}{\phi_{GB}+\phi_{BG}}. \tag{A.7}$$

A.2 Representative agent's continuation value

Lemma A.1. *In equilibrium, the representative agent's continuation value, as a function of the representative's consumption, C_t, and state variables p_t, $p_0(t)$, $\lambda_{2,t}$ and τ, is given by*

$$J(C_t, p_t, p_0(t), \lambda_{2,t}, \tau) = \frac{1}{1-\gamma} C_t^{1-\gamma} I(p_t, p_0(t), \lambda_{2,t}, \tau)^{1-\gamma}, \tag{A.8}$$

where

$$I(p_t, p_0(t), \lambda_{2,t}, \tau) = \exp\{a\big(\tau; p_0(t)\big) + b_p p + b_\lambda \lambda_{2,t}\}, \tag{A.9}$$

and the coefficients are given by

$$b_p = \frac{(\lambda^B - \lambda^G) E_\nu \left[e^{(1-\gamma)Z_{1,t}} - 1\right]}{(1-\gamma)(\beta + \phi_{GB} + \phi_{BG})}, \tag{A.10}$$

$$b_\lambda = \frac{1}{(1-\gamma)\sigma_\lambda^2} \left(\beta + \kappa - \sqrt{(\beta+\kappa)^2 - 2\sigma_\lambda^2 [E_\nu e^{(1-\gamma)Z_{2,t}} - 1]}\right). \tag{A.11}$$

and

$$a\big(\tau; p_0(t)\big) = \zeta_{p_0(t)} e^{\beta\tau} + \frac{1}{\beta}\left(\mu - \frac{1}{2}\gamma\sigma^2 + b_p \phi_{GB} + b_\lambda \kappa \bar{\lambda} + \frac{\lambda^G}{1-\gamma}\left[E_\nu e^{(1-\gamma)Z_{1,t}} - 1\right]\right). \tag{A.12}$$

ζ_0 and ζ_1 are the solution to the following system of equations:

$$\begin{aligned} e^{(1-\gamma)(\zeta_0 e^{\beta T} + b_p p^G)} &= p^G e^{(1-\gamma)(\zeta_1 + b_p)} + (1 - p^G) e^{(1-\gamma)\zeta_0} \\ e^{(1-\gamma)(\zeta_1 e^{\beta T} + b_p p^B)} &= p^B e^{(1-\gamma)(\zeta_1 + b_p)} + (1 - p^B) e^{(1-\gamma)\zeta_0}, \end{aligned} \tag{A.13}$$

where $p^G = p(T^-; 0)$, $p^B = p(T^-; 1)$, and the function $p(\tau; p_0)$ is defined as

$$p(\tau; p_0) = \left(p_0 - \frac{\phi_{GB}}{\phi_{GB} + \phi_{BG}}\right) e^{-(\phi_{GB}+\phi_{BG})\tau} + \frac{\phi_{GB}}{\phi_{GB} + \phi_{BG}}.$$

Here E_ν is the expectation with respect to distribution ν.

Proof. Let $J(C_t, p_t, p_0(t), \lambda_{2,t}, \tau)$ be the representative agent's value function at time t, given the representative agent's consumption C_t, p_t, $p_0(t)$, $\lambda_{2,t}$ and τ. For $\tau \in [0, T)$, the optimality implies that $J(C_t, p_t, p_0(t), \lambda_{2,t}, \tau)$ should be characterized by the following Hamilton-Jacobi-Bellman

Equation,

$$
\begin{aligned}
f(C_t, J_t) + \frac{\partial J}{\partial \tau} + \frac{\partial J}{\partial C} C_t \mu + \frac{\partial J}{\partial p}\left[-p(\phi_{GB} + \phi_{BG}) + \phi_{GB}\right] - \frac{\partial J}{\partial \lambda}\kappa(\lambda_{2,t} - \bar{\lambda}) \\
+ \frac{1}{2}\frac{\partial^2 J}{\partial C^2} C_t^2 \sigma^2 + \frac{1}{2}\frac{\partial^2 J}{\partial \lambda^2}\lambda_{2,t}\sigma_\lambda^2 \\
+ \left[p\lambda^B + (1-p)\lambda^G\right] \bar{\mathcal{J}}_1\big(J(C_t, p_t, p_0(t), \lambda_{2,t}, \tau)\big) + \lambda_{2,t}\bar{\mathcal{J}}_2\big(J(C_t, p_t, p_0(t), \lambda_{2,t}, \tau)\big) = 0.
\end{aligned}
\tag{A.14}
$$

When $\tau = 0$, or upon announcements, agent's value function at t^- can be written as

$$
\begin{aligned}
V_{t^-} &= E\left[\int_t^\infty f(C_s, V_s)ds \,|\, \mathcal{F}_{t^-}\right] \\
&= E\left[E\Big[\int_t^\infty f(C_s, V_s)ds \,|\, \mathcal{F}_t\Big] \,|\, \mathcal{F}_{t^-}\right] \\
&= E\Big[V_t \,|\, \mathcal{F}_{t^-}\Big],
\end{aligned}
\tag{A.15}
$$

or equivalently,

$$
J(C_{t^-}, p_{t^-}, p_0(t^-), \lambda_{2,t^-}, T^-) = E\left[J(C_t, p_t, p_0(t), \lambda_{2,t}, 0)\Big|\mathcal{F}_{t^-}\right]. \tag{A.16}
$$

Note that, C_t and $\lambda_{2,t}$ does not change upon announcements, we then can write

$$
J(C_t, p_{t^-}, p_0(t^-), \lambda_{2,t}, T^-) = E\left[J(C_t, p_t, p_0(t), \lambda_{2,t}, 0)\Big|\mathcal{F}_{t^-}\right],
$$

for t such that $t \bmod T = 0$.

Conjecture that

$$
J(C_t, p_t, p_0(t), \lambda_{2,t}, \tau) = \frac{1}{1-\gamma} C_t^{1-\gamma} I(p_t, p_0(t), \lambda_{2,t}, \tau)^{1-\gamma}, \tag{A.17}
$$

where

$$
I(p_t, p_0(t), \lambda_{2,t}, \tau) = e^{a\left(\tau; p_0(t)\right) + b_p p + b_\lambda \lambda_{2,t}}. \tag{A.18}
$$

We first know that under this specification, we have

$$
\begin{aligned}
\frac{\bar{\mathcal{J}}_1\left[J(C_t, p_t, p_0(t), \lambda_{2,t}, \tau)\right]}{J(C_t, p_t, p_0(t), \lambda_{2,t}, \tau)} &= E_\nu\left[e^{(1-\gamma)Z_{1,t}} - 1\right] \\
\frac{\bar{\mathcal{J}}_2\left[J(C_t, p_t, p_0(t), \lambda_{2,t}, \tau)\right]}{J(C_t, p_t, p_0(t), \lambda_{2,t}, \tau)} &= E_\nu\left[e^{(1-\gamma)Z_{2,t}} - 1\right],
\end{aligned}
\tag{A.19}
$$

where E_ν denotes the expectation with respect to distribution ν.

Plug (A.17) into (A.14) and then divide both sides by J, we obtain the following equation:

$$
\begin{aligned}
&-\beta(1-\gamma)\Big[a\big(\tau;p_0(t)\big)+b_p p+b_\lambda\lambda_{2,t}\Big]\\
&+(1-\gamma)\frac{\partial a}{\partial\tau}(\tau;p_0(t))+(1-\gamma)\bar{\mu}_C+(1-\gamma)b_p\left[-p(\phi_{GB}+\phi_{BG})+\phi_{GB}\right]-(1-\gamma)b_\lambda\kappa(\lambda_{2,t}-\bar{\lambda}_2)\\
&\qquad-\frac{1}{2}\gamma(1-\gamma)\sigma^2+\frac{1}{2}(1-\gamma)^2 b_\lambda^2\sigma_\lambda^2\lambda_{2,t}\\
&+p(\lambda^B-\lambda^G)E_\nu\left[e^{(1-\gamma)Z_{1,t}}-1\right]+\lambda^G E_\nu\left[e^{(1-\gamma)Z_{1,t}}-1\right]+\lambda_{2,t}\left[E_\nu e^{(1-\gamma)Z_{2,t}}-1\right]=0.
\end{aligned}
\tag{A.20}
$$

Collect the coefficients of $\lambda_{2,t}$ and p_t, we can obtain the following equations:

$$
\begin{aligned}
-\beta(1-\gamma)b_p-(1-\gamma)b_p(\phi_{GB}+\phi_{BG})+(\lambda^B-\lambda^G)E_\nu\left[e^{(1-\gamma)Z_{1,t}}-1\right]&=0\\
-\beta(1-\gamma)b_\lambda-(1-\gamma)b_\lambda\kappa+\frac{1}{2}(1-\gamma)^2 b_\lambda^2\sigma_\lambda^2+E_\nu\left[e^{(1-\gamma)Z_{2,t}}-1\right]&=0.
\end{aligned}
\tag{A.21}
$$

Then we have

$$
b_p=\frac{(\lambda^B-\lambda^G)E_\nu\left[e^{(1-\gamma)Z_{1,t}}-1\right]}{(1-\gamma)(\beta+\phi_{GB}+\phi_{BG})}.
\tag{A.22}
$$

We also have the following quadratic function of b_λ:

$$
\frac{1}{2}(1-\gamma)\sigma_\lambda^2 b_\lambda^2-(\beta+\kappa)b_\lambda+\frac{1}{1-\gamma}E_\nu\left[e^{(1-\gamma)Z_{2,t}}-1\right]=0,
\tag{A.23}
$$

which has the following solution[7]:

$$
b_\lambda=\frac{1}{(1-\gamma)\sigma_\lambda^2}\left(\beta+\kappa-\sqrt{(\beta+\kappa)^2-2\sigma_\lambda^2 E_\nu\left[e^{(1-\gamma)Z_{2,t}}-1\right]}\right).
\tag{A.24}
$$

Finally we solve $a\big(\tau;p_0(t)\big)$. $a\big(\tau;p_0(t)\big)$ is characterized by the following O.D.E:

$$
\begin{aligned}
&-\beta(1-\gamma)a\big(\tau;p_0(t)\big)\\
&+(1-\gamma)\frac{\partial a}{\partial\tau}(\tau;p_0(t))+(1-\gamma)\bar{\mu}_C+(1-\gamma)b_p\phi_{GB}+(1-\gamma)b_\lambda\kappa\bar{\lambda}-\frac{1}{2}\gamma(1-\gamma)\sigma^2+\lambda^G E_\nu\left[e^{(1-\gamma)Z_{1,t}}-1\right]=0.
\end{aligned}
$$

[7]See Tsai and Wachter (2016) for details about choosing the solution to b_λ.

Or equivalently, we can write the following O.D.E:

$$\frac{\partial a}{\partial \tau}(\tau;p_0(t)) = \beta a\big(\tau;p_0(t)\big) - \bar{\mu}_C + \frac{1}{2}\gamma\sigma^2 - b_p\phi_{GB} - b_\lambda\kappa\bar{\lambda} - \frac{\lambda^G}{1-\gamma}E_\nu\left[e^{(1-\gamma)Z_{1,t}} - 1\right].$$

Then we have the following general form of $a\big(\tau;p_0(t)\big)$:

$$a\big(\tau;p_0(t)\big) = \zeta_{p_0(t)}e^{\beta\tau} + \frac{1}{\beta}\left(\mu - \frac{1}{2}\gamma\sigma^2 + b_p\phi_{GB} + b_\lambda\kappa\bar{\lambda} + \frac{\lambda^G}{1-\gamma}E_\nu\left[e^{(1-\gamma)Z_{1,t}} - 1\right]\right), \quad \text{(A.25)}$$

where ζ_1 and ζ_0 are two un-determined constant terms. We will solve them in what follows.

Condition A.16 gives another restriction on $a\big(\tau;p_0(t)\big)$:

$$\exp\left\{(1-\gamma)\left[a\big(T^-;p_0(t^-)\big) + b_p p(T^-;p_0(t^-))\right]\right\} = E\left[\exp\left\{(1-\gamma)\left[a\big(0;p(t)\big) + b_p p(0;p(t))\right]\right\}\Big|\mathcal{F}_{t^-}\right],$$

for $p_0(t^-)$ and $p_0(t^)$ being 0 or 1.

Define $p^G = p(T^-;0)$, $p^B = p(T^-;1)$

This leads to the following system of equations,

$$e^{(1-\gamma)\left(\zeta_0 e^{\beta T} + b_p p^G\right)} = p^G e^{(1-\gamma)(\zeta_1 + b_p)} + (1-p^G)e^{(1-\gamma)\zeta_0}$$
$$e^{(1-\gamma)\left(\zeta_1 e^{\beta T} + b_p p^B\right)} = p^B e^{(1-\gamma)(\zeta_1 + b_p)} + (1-p^B)e^{(1-\gamma)\zeta_0},$$

which uniquely pins down ζ_0 and ζ_1. □

A.3 The state price density

Lemma A.2. *The process of state price density, π_t, can be characterized by the following equation:*

$$\pi_t = \beta \exp\left\{\int_0^t \frac{\partial}{\partial V} f(C_s, V_s) ds\right\} C_t^{-\gamma} I(p_t, p_0(t), \lambda_{2,t}, \tau)^{1-\gamma}, \tag{A.26}$$

where $I(p_t, p_0(t), \lambda_{2,t}, \tau)$ is defined by Equation A.9.

Proof. We know that,

$$\pi_t = \exp\left\{\int_0^t \frac{\partial}{\partial V} f(C_s, V_s) ds\right\} \frac{\partial}{\partial C} f(C_t, V_t). \tag{A.27}$$

We also know that

$$\begin{aligned}
\frac{\partial}{\partial C} f(C_t, V_t) &= \beta(1-\gamma)\frac{V_t}{C_t} \\
&= \beta(1-\gamma)\frac{(1-\gamma)^{-1}(C_t)^{1-\gamma} I(p_t, p_0(t), \lambda_{2,t}, \tau)^{1-\gamma}}{C_t} \\
&= \beta C_t^{-\gamma} I(p_t, p_0(t), \lambda_{2,t}, \tau)^{1-\gamma}.
\end{aligned} \tag{A.28}$$

Combining Equation A.27 and A.28, we can then get

$$\pi_t = \beta \exp\left\{\int_0^t \frac{\partial}{\partial V} f(C_s, V_s) ds\right\} C_t^{-\gamma} I(p_t, p_0(t), \lambda_{2,t}, \tau)^{1-\gamma}.$$

□

Proof of Theorem 1. We know that

$$\begin{aligned}
\frac{\partial}{\partial V} f(C_t, V_t) &= \frac{\partial}{\partial V}\Big(\beta(1-\gamma)V_t \log C_t - \beta V_t \log[(1-\gamma)V_t]\Big) \\
&= \beta(1-\gamma)\log C_t - \beta \log[(1-\gamma)V_t] - \beta \\
&= -\beta\left\{1 + (1-\gamma)[a\big(\tau; p_0(t)\big) + b_p p + b_\lambda \lambda_{2,t}]\right\}.
\end{aligned} \tag{A.29}$$

Then by Itô's Lemma, with Equation A.26, it is easy to show that during non-announcement periods,

$$\begin{aligned}\frac{d\pi_t}{\pi_{t^-}} = &\left\{-\beta\Big[1+(1-\gamma)a\big(\tau;p_0(t)\big)+(1-\gamma)b_p p+(1-\gamma)b_\lambda\lambda_{2,t}\Big]+(1-\gamma)\frac{\partial a}{\partial\tau}\right\}dt\\
&-\gamma\mu dt+(1-\gamma)b_p\left[-p\phi_{BG}+(1-p)\phi_{GB}\right]dt-(1-\gamma)b_\lambda\kappa(\lambda_{2,t}-\bar{\lambda})dt\\
&+\frac{1}{2}\gamma(\gamma+1)\sigma^2dt+\frac{1}{2}(1-\gamma)^2b_\lambda^2\sigma_\lambda^2\lambda_{2,t}dt\\
&-\gamma\sigma dB_{C,t}+(1-\gamma)b_\lambda\sigma_\lambda\sqrt{\lambda_{2,t}}dB_{\lambda,t}\\
&+\left(e^{-\gamma Z_{1,t}}-1\right)dN_{1,t}+\left(e^{-\gamma Z_{2,t}}-1\right)dN_{2,t}.\end{aligned}\tag{A.30}$$

Clean up, and with the Equations that characterizing $a\big(\tau;p_0(t)\big)$, b_p and b_λ, we then have

$$\begin{aligned}\frac{d\pi_t}{\pi_{t^-}} = &-\Big\{\beta+\bar{\mu}_C-\gamma\sigma^2+\bar{\lambda}(p)\big[E_\nu e^{(1-\gamma)Z_{1,t}}-1\big]+\lambda_{2,t}E_\nu\big[e^{(1-\gamma)Z_{2,t}}-1\big]\Big)dt\\
&-\gamma\sigma dB_{C,t}+(1-\gamma)b_\lambda\sigma_\lambda\sqrt{\lambda_{2,t}}dB_{\lambda,t}+\left(e^{-\gamma Z_{1,t}}-1\right)dN_{1,t}+\left(e^{-\gamma Z_{2,t}}-1\right)dN_{2,t},\end{aligned}\tag{A.31}$$

where $\bar{\lambda}(p_t)$ is as defined before.

We can further clean up, and get[8]

$$\begin{aligned}\frac{d\pi_t}{\pi_{t^-}} &= -\left\{\beta+\bar{\mu}_C-\gamma\sigma^2+\bar{\lambda}(p_t)E_\nu\big[e^{-\gamma Z_{1,t}}(e^{Z_{1,t}}-1)\big]+\lambda_{2,t}E_\nu\big[e^{-\gamma Z_{2,t}}(e^{Z_{2,t}}-1)\big]\right\}dt\\
&\quad-\bar{\lambda}(p)E_\nu\big[e^{-\gamma Z_{1,t}}-1\big]dt-\lambda_{2,t}E_\nu\big[e^{-\gamma Z_{2,t}}-1\big]dt\\
&\quad-\gamma\sigma dB_{C,t}+(1-\gamma)b_\lambda\sigma_\lambda\sqrt{\lambda_{2,t}}dB_{\lambda,t}+\left(e^{-\gamma Z_{1,t}}-1\right)dN_{1,t}+\left(e^{-\gamma Z_{2,t}}-1\right)dN_{2,t},\\
&= -r_tdt-\bar{\lambda}(p_t)E_\nu\big[e^{-\gamma Z_{1,t}}-1\big]dt-\lambda_{2,t}E_\nu\big[e^{-\gamma Z_{2,t}}-1\big]dt\\
&\quad-\gamma\sigma dB_{C,t}+(1-\gamma)b_\lambda\sigma_\lambda\sqrt{\lambda_{2,t}}dB_{\lambda,t}+\left(e^{-\gamma Z_{1,t}}-1\right)dN_{1,t}+\left(e^{-\gamma Z_{2,t}}-1\right)dN_{2,t}.\end{aligned}\tag{A.32}$$

For $\tau=0$, or upon announcements, we can see from the derivation of $I(p_t,p_0(t),\lambda_{2,t},\tau)$ that there is a jump of p_t and $p_0(t)$ after the revealing of $\lambda_{1,t}$. This then can be characterized as

$$\frac{\pi_t}{\pi_{t^-}}=\frac{e^{(1-\gamma)(a(0;p_0(t))+b_pp_t)}}{e^{(1-\gamma)(a(T^-;p_0(t^-))+b_pp_{t^-})}},\forall p_0(t).\tag{A.33}$$

By the smooth condition of the value function, we know that

$$E\left[\frac{\pi_t}{\pi_{t^-}\times 1}\Big|\mathcal{F}_{t^-}\right]=1.\tag{A.34}$$

[8]See Wachter (2013) for solution to r_t.

Intuitively, one dollar paid immediately after the announcement should have price 1 right before the announcement, as there is no maturity allowed for discounting.

□

A.3.1 State price density on announcements

Proof of Corollary 2.1. We want to show $\zeta_0 > \zeta_1 + b_p$. We prove this by contradiction.

Suppose that $\zeta_0 \leq \zeta_1 + b_p$.

Note that, the system of equations that determines ζ_0 and ζ_1 is given by

$$e^{(1-\gamma)\left(\zeta_0 e^{\beta T} + b_p p^G\right)} = p^G e^{(1-\gamma)(\zeta_1 + b_p)} + (1-p^G)e^{(1-\gamma)\zeta_0}$$
$$e^{(1-\gamma)\left(\zeta_1 e^{\beta T} + b_p p^B\right)} = p^B e^{(1-\gamma)(\zeta_1 + b_p)} + (1-p^B)e^{(1-\gamma)\zeta_0},$$

Obviously, $0 < p^G < p^B < 1$, given that $T > 0$.

This then implies that

$$(1-\gamma)\zeta_0 \geq (1-\gamma)(\zeta_0 e^{\beta T} + b_p p^G) \geq (1-\gamma)(\zeta_1 e^{\beta T} + b_p p^B) \geq (1-\gamma)(\zeta_1 + b_p),$$

as $1-\gamma < 0$. We have

$$\begin{aligned} &\zeta_0 \leq \zeta_0 e^{\beta T} + b_p p^G \\ \Rightarrow &- b_p p^G \leq \zeta_0 (e^{\beta T} - 1) \\ \Rightarrow &\zeta_0 > 0, \text{ as } e^{\beta T} - 1 > 0, b_p < 0. \end{aligned}$$

Similarly, we have

$$\begin{aligned} &\zeta_1 e^{\beta T} + b_p p^B \leq \zeta_1 + b_p \\ \Rightarrow &\zeta_1 (e^{\beta T} - 1) \leq b_p (1 - p^B) < 0. \\ \Rightarrow &\zeta_1 < 0. \end{aligned}$$

However, this means that

$$\zeta_1 + b_p < \zeta_1 < 0 < \zeta_0,$$

which is a contradiction. □

B Pricing equity

In this section we start with characterizing the process of the price for dividend claim. Then we use the characterization to solve the price of dividend assets.

B.1 Pricing zero-coupon risky dividend payment during non-announcement periods

Lemma B.1. *Let $H_t = H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, t^* - t)$ denote the time-t price of a future dividend paid at time t^*, then*

$$H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, t^* - t) = E_t\left[\frac{\pi_{t^*}}{\pi_t} D_{t^*}\right]. \tag{B.1}$$

Moreover, during non-announcement periods, or for t such that $t \bmod T \neq 0$, there exist processes $\mu_{H,t} = \mu_H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, t^* - t)$ and $\sigma_{H,t} = \sigma_H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, t^* - t)$, such that

$$\frac{dH_t}{H_{t^-}} = \mu_{H,t}dt + \sigma_{H,t}dB_t + \frac{\mathcal{J}_1(H_t)}{H_{t^-}}dN_{1,t} + \frac{\mathcal{J}_2(H_t)}{H_{t^-}}dN_{2,t}, \tag{B.2}$$

and

$$\mu_{H,t} + \mu_{\pi,t} + \sigma_{H,t}^\top \sigma_{\pi,t} + \bar{\lambda}(p_t)\frac{\bar{\mathcal{J}}_1(H_t\pi_t)}{H_t\pi_t} + \lambda_{2,t}\frac{\bar{\mathcal{J}}_2(H_t\pi_t)}{H_t\pi_t} = 0. \tag{B.3}$$

Proof. Part 1 follows the definition of state price density.

Obviously

$$\pi_t H_t = E_t(\pi_{t^*} H_{t^*}), \tag{B.4}$$

or $\pi_t H_t$ is a martingale.

Locally, there exist processes $\mu_{H,t} = \mu_H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, t^* - t)$ and $\sigma_{H,t} = \sigma_H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, t^* - t)$, such that

$$\frac{dH_t}{H_{t^-}} = \mu_{H,t}dt + \sigma_{H,t}dB_t + \frac{\mathcal{J}_1(H_t)}{H_{t^-}}dN_{1,t} + \frac{\mathcal{J}_2(H_t)}{H_{t^-}}dN_{2,t}. \tag{B.5}$$

Then by Itô's lemma, we have

$$\begin{aligned} H_{t+\Delta t}\pi_{t+\Delta t} = H_t\pi_t &+ \int_{t^+}^{t+\Delta t} \pi_s H_s(\mu_{H,s} + \mu_{\pi,s} + \sigma_{H,s}^\top \sigma_{\pi,s})ds + \int_{t^+}^{t+\Delta t} \pi_s H_s(\sigma_{H,s} + \sigma_{\pi,s})dB_s \\ &+ \sum_{j=1,2}\sum_{t<s_{j,l}\leq t+\Delta t} (\pi_{s_{j,l}} H_{s_{j,l}} - \pi_{s_{j,l^-}} H_{s_{j,l^-}}), \end{aligned} \tag{B.6}$$

for some arbitrarily small Δt such that t and $t + \Delta t$ are in the same non-announcement period. Here

$$s_{j,l} = \inf\{t : N_{j,l} = j\}, \quad j = 1, 2, \tag{B.7}$$

are the arrival times of the two Poisson processes.

Note that, $\forall\ s$, such that $t < s \leq t + \Delta t$, $s \neq s_j$, $\forall j$, $\mathcal{J}(H_t \pi_t) = 0$. As a result we can write

$$\sum_{t < s_{j,l} < t+\Delta t} (\pi_{s_{j,l}} H_{s_{j,l}} - \pi_{s_{j,l^-}} H_{s_{j,l^-}}) = \int_{t^+}^{t+\Delta t} \mathcal{J}_j(H_s \pi_s) ds, j = 1, 2. \tag{B.8}$$

Obviously,

$$E_t \left[\sum_{t < s_{j,l} \leq t+\Delta t} (\pi_{s_{j,l}} H_{s_{j,l}} - \pi_{s_{j,l^-}} H_{s_{j,l^-}}) - \int_{t^+}^{t+\Delta t} \mathcal{J}_j(H_s \pi_s) ds \right] = 0, j = 1, 2. \tag{B.9}$$

In addition, we can write

$$\begin{aligned} 0 &= E_t \left[\sum_{t < s_{j,l} \leq t+\Delta t} (\pi_{s_{j,l}} H_{s_{j,l}} - \pi_{s_{j,l^-}} H_{s_{j,l^-}}) - \int_{t^+}^{t+\Delta t} \mathcal{J}_j(H_s \pi_s) ds \right] \\ &= E_t \left\{ \sum_{t < s_{j,l} \leq t+\Delta t} (\pi_{s_{j,l}} H_{s_{j,l}} - \pi_{s_{j,l^-}} H_{s_{j,l^-}}) - \int_{t^+}^{t+\Delta t} E[\mathcal{J}_j(H_s \pi_s) ds \,|\, \mathcal{F}_{s^-}] ds \right\}. \end{aligned} \tag{B.10}$$

As a result[9],

$$\begin{aligned} E_t \left[\sum_{t < s_{1,l} \leq t+\Delta t} (\pi_{s_{1,l}} H_{s_{1,l}} - \pi_{s_{1,l^-}} H_{s_{1,l^-}}) - \int_{t^+}^{t+\Delta t} \bar{\lambda}(p_s) \bar{\mathcal{J}}_1(H_s \pi_s) ds \right] &= 0, \\ E_t \left[\sum_{t < s_{2,l} \leq t+\Delta t} (\pi_{s_{2,l}} H_{s_{2,l}} - \pi_{s_{2,l^-}} H_{s_{2,l^-}}) - \int_{t^+}^{t+\Delta t} \lambda_{2,s} \bar{\mathcal{J}}_2(H_s \pi_s) ds \right] &= 0. \end{aligned} \tag{B.11}$$

[9]Here Law of Iterated Expectations is used.

We then can rewrite Equation B.6 as

$$H_{t+\Delta t}\pi_{t+\Delta t} = H_t\pi_t + \underbrace{\int_{t^+}^{t+\Delta t} \pi_s H_s \left(\mu_{H,s} + \mu_{\pi,s} + \sigma_{H,s}^\top \sigma_{\pi,s} + \bar{\lambda}(p_s)\frac{\bar{\mathcal{J}}_1(H_s\pi_s)}{H_s\pi_s} + \lambda_{2,s}\frac{\bar{\mathcal{J}}_2(H_s\pi_s)}{H_s\pi_s}\right) ds}_{(1)}$$

$$+ \underbrace{\int_{t^+}^{t+\Delta t} \pi_s H_s(\sigma_{H,s} + \sigma_{\pi,s}) dB_s}_{(2)}$$

$$+ \underbrace{\sum_{t<s_{1,l}\leq t+\Delta t} (\pi_{s_{1,l}} H_{s_{1,l}} - \pi_{s_{1,l^-}} H_{s_{1,l^-}}) - \int_{t^+}^{t+\Delta t} \bar{\lambda}(p_s)\bar{\mathcal{J}}_1(H_s\pi_s) ds}_{(3)}$$

$$+ \underbrace{\sum_{t<s_{2,l}\leq t+\Delta t} (\pi_{s_{2,l}} H_{s_{2,l}} - \pi_{s_{2,l^-}} H_{s_{2,l^-}}) - \int_{t^+}^{t+\Delta t} \lambda_{2,s}\bar{\mathcal{J}}_2(H_s\pi_s) ds}_{(4)}. \quad \text{(B.12)}$$

Since $H_t\pi_t$ is a matingale, the time t expectation of $H_{t+\Delta t}\pi_{t+\Delta t}$ must be $H_t\pi_t$. In Equation B.12, (2) apparently has expectation 0 at time t, and (3) and (4) are showed to have expectation 0. As a result, the integrand in (1) must be 0, $\forall s$. Since $H_s\pi_s > 0$, $\forall s$. Extend this argument to any arbitrary t, we obtain

$$\mu_{H,t} + \mu_{\pi,t} + \sigma_{H,t}^\top \sigma_{\pi,t} + \lambda_{1,t}\frac{\bar{\mathcal{J}}_1(H_t\pi_t)}{H_t\pi_t} + \lambda_2\frac{\bar{\mathcal{J}}_2(H_t\pi_t)}{H_t\pi_t} = 0, \forall t. \quad \text{(B.13)}$$

$\square$

B.2 Pricing a stream of dividends during non-announcement periods

Lemma B.2. *Let $F_t = F(D_t, p_t, p_0(t), \lambda_{2,t}, \tau)$ denote the time-t ex-dividend price of a future dividend stream $\{D_s\}_{s\in(t,\infty)}$, then during non-announcement periods, or for t such that $t \bmod T \neq 0$, there exist processes $\mu_{F,t} = \mu_F(D_t, p_t, p_0(t), \lambda_{2,t}, \tau)$ and $\sigma_{F,t} = \sigma_F(D_t, p_t, p_0(t), \lambda_{2,t}, \tau)$ such that*

$$\mu_{\pi,t} + \mu_{F,t} + \frac{D_t}{F_t} + \sigma_{\pi,t}^\top \sigma_{F,t} + \bar{\lambda}(p_t)\frac{\bar{\mathcal{J}}_1(\pi_t F_t)}{\pi_t F_t} + \lambda_{2,t}\frac{\bar{\mathcal{J}}_2(\pi_t F_t)}{\pi_t F_t} = 0. \quad \text{(B.14)}$$

Proof. Obviously by non-arbitrage we have

$$F(D_t, p_t, p_0(t), \lambda_{2,t}, \tau) = \int_0^\infty H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, s) ds. \quad \text{(B.15)}$$

Again we know that locally there exists $\mu_{F,t} = \mu_F(D_t, p_t, p_0(t), \lambda_{2,t}, \tau)$ and $\sigma_{F,t} = \sigma_F(D_t, p_t, p_0(t), \lambda_{2,t}, \tau)$

such that

$$\frac{dF_t}{F_{t^-}} = \mu_{F,t}dt + \sigma_{F,t}dB_t + dN_{1,t}\frac{\mathcal{J}_1(F_t)}{F_{t^-}} + dN_{2,t}\frac{\mathcal{J}_2(F_t)}{F_{t^-}}. \tag{B.16}$$

Let $\mu_{H(s),t} = \mu_H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, s)$ and $\sigma_{H(s),t} = \sigma_H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, s)$, $s \in [0, \infty)$. Apply Itô's lemma on both sides of Equation B.15, and we get

$$F(D_t, p_t, p_0(t), \lambda_{2,t}, \tau)\sigma_{F,t} = \int_0^\infty H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, s)\sigma_{H(s),t}ds. \tag{B.17}$$

In addition, we have

$$\begin{aligned}\mathcal{J}_j(\pi_t F(D_t, p_t, p_0(t), \lambda_{2,t}, \tau)) &= \mathcal{J}_j\left(\pi_t \int_0^\infty H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, s)ds\right) \\ &= \int_0^\infty \mathcal{J}_j\big(\pi_t H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau s)\big)ds, j = 1, 2.\end{aligned} \tag{B.18}$$

The second equality holds due to the definition of operator $\mathcal{J}$. Take conditional expectation of both sides with respect to Z_t, and we have

$$\bar{\mathcal{J}}_j\big(\pi_t F(D_t, p_t, p_0(t), \lambda_{2,t}, \tau)\big) = \int_0^\infty \bar{\mathcal{J}}_j\big(\pi_t H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, s)\big)ds, j = 1, 2. \tag{B.19}$$

Finally, by the definition of $dF(D_t, p_t, p_0(t), \lambda_{2,t}, \tau)$ we can see

$$F(D_t, p_t, p_0(t), \lambda_{2,t}, \tau)\mu_{F,t} = \int_0^\infty H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, s)\mu_{H(s),t}ds - D_t. \tag{B.20}$$

D_t term shows up as $H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, 0) = D_t$. Then we have

$$\begin{aligned}&\mu_{F,t} + \frac{D_t}{F_t} + \sigma_{\pi,t}^\top \sigma_{F,t} + \bar{\lambda}(p_t)\frac{\bar{\mathcal{J}}_1(\pi_t F_t)}{\pi_t F_t} + \lambda_{2,t}\frac{\bar{\mathcal{J}}_2(\pi_t F_t)}{\pi_t F_t} \\ =&\frac{1}{F_t}\left(\int_0^\infty H_t(s)\mu_{H(s),t}ds\right) + \frac{1}{F_t}\sigma_{\pi,t}^\top \int_0^\infty H_t(s)\sigma_{H(s),t}ds \\ &\quad + \bar{\lambda}(p_t)\frac{1}{\pi_t F_t}\int_0^\infty \bar{\mathcal{J}}_1(\pi_t H_t(s))ds + \lambda_{2,t}\frac{1}{\pi_t F_t}\int_0^\infty \bar{\mathcal{J}}_2(\pi_t H_t(s))ds \\ =&\frac{1}{F_t}\int_0^\infty H_t(s)\left(\mu_{H(s),t} + \sigma_{\pi,t}^\top \sigma_{H(s),t} + \bar{\lambda}(p_t)\frac{1}{\pi_t H_t}\bar{\mathcal{J}}_1(\pi_t H_t(s)) + \lambda_{2,t}\frac{1}{\pi_t H_t}\bar{\mathcal{J}}_2(\pi_t H_t(s))\right)ds \\ =&\frac{1}{F_t}\int_0^\infty H_t(s)(-\mu_{\pi,t})ds \\ =&-\mu_{\pi,t}\frac{1}{F_t}\int_0^\infty H_t(s)ds \\ =&-\mu_{\pi,t},\end{aligned} \tag{B.21}$$

where $H_t(s) = H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, s)$.

Reorder, and we can get

$$\mu_{\pi,t} + \mu_{F,t} + \frac{D_t}{F_t} + \sigma_{\pi,t}^\top \sigma_{F,t} + \bar{\lambda}(p_t)\frac{\bar{\mathcal{J}}_1(\pi_t F_t)}{\pi_t F_t} + \lambda_{2,t}\frac{\bar{\mathcal{J}}_2(\pi_t F_t)}{\pi_t F_t} = 0.$$

□

B.3 The premium of a dividend stream claim during non-announcement periods

Lemma B.3. *For a asset with claim to a stream of dividend with time-t price $F(D_t, p_t, p_0(t), \lambda_{2,t}, \tau)$, its instantaneous premium during non-announcement period is given by*

$$-\sigma_{\pi,t}^\top \sigma_{F,t} - \bar{\lambda}(p_t) E_\nu \left[\frac{\mathcal{J}_1(\pi_t)}{\pi_t} \frac{\mathcal{J}_1(F_t)}{F_t} \right] - \lambda_{2,t} E_\nu \left[\frac{\mathcal{J}_2(\pi_t)}{\pi_t} \frac{\mathcal{J}_2(F_t)}{F_t} \right]. \tag{B.22}$$

Proof. The expected instantaneous return of a dividend stream $F(D_t, p_t, p_0(t), \lambda_{2,t}, \tau)$ is

$$\begin{aligned}
& E_t \frac{(dF_t + D_t dt)/F_t}{dt} \\
&= \mu_{F,t} + \frac{D_t}{F_t} + \bar{\lambda}(p_t)\frac{\bar{\mathcal{J}}_1(F_t)}{F_t} + \lambda_{2,t}\frac{\bar{\mathcal{J}}_2(F_t)}{F_t} \\
&= -\mu_{\pi,t} - \sigma_{\pi,t}^\top \sigma_{F,t} - \bar{\lambda}(p_t)\frac{\bar{\mathcal{J}}_1(\pi_t F_t)}{\pi_t F_t} + \bar{\lambda}(p_t)\frac{\bar{\mathcal{J}}_1(F_t)}{F_t} - \lambda_{2,t}\frac{\bar{\mathcal{J}}_2(\pi_t F_t)}{\pi_t F_t} + \lambda_{2,t}\frac{\bar{\mathcal{J}}_2(F_t)}{F_t} \\
&= r_t - \sigma_{\pi,t}^\top \sigma_{F,t} + \bar{\lambda}(p_t)\frac{\bar{\mathcal{J}}_1(\pi_t)}{\pi_t} - \bar{\lambda}(p_t)\frac{\bar{\mathcal{J}}_1(\pi_t F_t)}{\pi_t F_t} + \bar{\lambda}(p_t)\frac{\bar{\mathcal{J}}_1(F_t)}{F_t} + \lambda_{2,t}\frac{\bar{\mathcal{J}}_2(\pi_t)}{\pi_t} - \lambda_{2,t}\frac{\bar{\mathcal{J}}_2(\pi_t F_t)}{\pi_t F_t} + \lambda_{2,t}\frac{\bar{\mathcal{J}}_2(F_t)}{F_t} \\
&= r_t - \sigma_{\pi,t}^\top \sigma_{F,t} - \bar{\lambda}(p_t) E_\nu \left[\frac{\mathcal{J}_1(\pi_t)}{\pi_t} \frac{\mathcal{J}_1(F_t)}{F_t} \right] - \lambda_{2,t} E_\nu \left[\frac{\mathcal{J}_2(\pi_t)}{\pi_t} \frac{\mathcal{J}_2(F_t)}{F_t} \right],
\end{aligned} \tag{B.23}$$

where r_t is the instantaneous risk-free rate. Subtract it from the formula above, we obtain the instantaneous premium. □

B.4 Pricing of levered consumption claim dividend assets

To simplify notations, we only consider one single asset with loadings on disasters being ϕ. The process of the dividend is then given by

$$\frac{dD_t}{D_t} = \bar{\mu}_D dt + \sigma dB_{C,t} + (e^{\phi Z_{1,t}} - 1) dN_{1,t} + (e^{\phi Z_{2,t}} - 1) dN_{2,t}, \tag{B.24}$$

where ϕ is the leverage on disasters.

Lemma B.4. *The time-t price of the claim to time-$t+s$ dividend, D_{t+s}, with dividend growth process given by (B.24), is*

$$H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, s) = D_t \exp\left\{a_\phi\big(\tau, s; p_0(t)\big) + b_{\phi,p}(s)p_t + b_{\phi,\lambda}(s)\lambda_{2,t}\right\}, \tag{B.25}$$

where

$$b_{\phi,p}(s) = \frac{(\lambda^B - \lambda^G)E_\nu\left[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}}\right]}{\phi_{BG} + \phi_{GB}}\left(1 - e^{-(\phi_{BG}+\phi_{GB})s}\right). \tag{B.26}$$

$b_{\phi,\lambda}(s)$ *is the solution to*

$$\frac{db_{\phi,\lambda}(s)}{ds} = \frac{1}{2}\sigma_\lambda^2 b_{\phi,\lambda}(s)^2 + \left[(1-\gamma)b_\lambda\sigma_\lambda^2 - \kappa\right]b_{\phi,\lambda}(s) + E_\nu\left[e^{(\phi-\gamma)Z_{2,t}} - e^{(1-\gamma)Z_{2,t}}\right], \tag{B.27}$$

with boundary condition

$$b_{\phi,\lambda}(0) = 0.$$

$a_\phi\big(\tau, s; p_0(t)\big)$ *is given by*

$$a_\phi\big(\tau, s; p_0(t)\big) = h\big(n, \tau, s; p_0(t)\big) + \int_0^s \left(-\beta - \mu + \bar{\mu}_D + \lambda^G E_\nu\left[e^{(\phi-\gamma)Z_t} - e^{(1-\gamma)Z_t}\right] + \kappa\bar{\lambda}b_{\phi,\lambda}(u)\right)du, \tag{B.28}$$

where $n = \left[\frac{\tau+s}{T}\right]$ is the number of announcements before the maturity, and $h\big(n, \tau, s; p_0(t)\big)$ is defined recursively by

1. $h\big(0, \tau, s; 0\big) = h\big(0, \tau, s; 1\big) = 0.$

2. *For* $k = 1, 2, 3, \ldots, n$

$$\begin{aligned}
h\big(k, \tau, s; 0\big) = \log\Big\{&p^G \exp^{(1-\gamma)(a(0;1)+b_p)+h\left(k-1,\tau,s;1\right)+b_{\phi,p}\left(s^*+(k-1)T\right)} + (1-p^G)\exp^{(1-\gamma)a(0;0)+h\left(k-1,\tau,s;0\right)}\Big\} \\
&- b_{\phi,p}\big(s^* + (k-1)T\big)p^G - (1-\gamma)b_p p^G - (1-\gamma)a(T^-; 0) \\
h\big(k, \tau, s; 1\big) = \log\Big\{&p^B \exp^{(1-\gamma)(a(0;1)+b_p)+h\left(k-1,\tau,s;1\right)+b_{\phi,p}\left(s^*+(k-1)T\right)} + (1-p^B)\exp^{(1-\gamma)a(0;0)+h\left(k-1,\tau,s;0\right)}\Big\} \\
&- b_{\phi,p}\big(s^* + (k-1)T\big)p^B - (1-\gamma)b_p p^B - (1-\gamma)a(T^-; 1),
\end{aligned} \tag{B.29}$$

where $s^* = (\tau + s) \bmod T$.

Proof. We conjecture that the time-t price of D_{t+s} is

$$H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, s) = D_t \exp\left\{a_\phi\big(\tau, s; p_0(t)\big) + b_{\phi,p}(s)p + b_{\phi,\lambda}(s)\lambda_{2,t}\right\}. \tag{B.30}$$

We start with showing the effect of announcements on asset prices that can be written in the form of (B.30).

We know that, for t such that $t \bmod T = 0$, we must have

$$D_{t^-} \exp\left\{a_\phi(T^-, s^+; p_0(t^-)) + b_{\phi,p}(s^+)p_{t^-} + b_{\phi,\lambda}(s^+)\lambda_{2,t^-}\right\}$$
$$= E\left[\frac{e^{(1-\gamma)(a(0;p_0(t))+b_p p_t)}}{e^{(1-\gamma)(a(T^-;p_0(t^-))+b_p p_{t^-})}} \times D_t \exp\left\{a_\phi(0, s; p_0(t)) + b_{\phi,p}(s)p_t + b_{\phi,\lambda}(s)\lambda_{2,t}\right\} \Big| \mathcal{F}_{t^-}\right]. \tag{B.31}$$

Note that $\lambda_{2,t^-} = \lambda_{2,t}$, $s^+ = s$ and $D_{t^-} = D_t$, with the solutions to $b_{\phi,p}(s)$ and $b_{\phi,\lambda}(s)$ before, we then have

$$\exp\left\{a_\phi\big(T^-, s; p_0(t)\big) + b_{\phi,p}(s)p_{t^-}\right\}$$
$$= E\left[\frac{e^{(1-\gamma)(a(0;p_0(t))+b_p p_t)}}{e^{(1-\gamma)(a(T^-;p_0(t^-))+b_p p_{t^-})}} \times \exp\left\{a_\phi(0, s; p_0(t)) + b_{\phi,p}(s)p_t\right\} \Big| \mathcal{F}_{t^-}\right], \tag{B.32}$$

where we use the fact that $p\big(0; p_0(t)\big) = p_0(t) = p_t$ when $t \bmod T = 0$.

Note that, when $t \bmod T = 0$, p_t can only take value 0 or 1, and p_{t^-} (which equals to $p(T^-; p_0(t^-))$) is a function of $p_0(t^-)$ only, we then can see that given s, the left hand side of (B.32) is only a function of $p_0(t^-)$. This then can imply that (B.32) can be extended into a two-equation system, which allows us to recursively solve for $a_\phi\big(\tau, s; p_0(t)\big)$. We will return to this later.

During non-announcement periods, with Itô's Lemma, we know that

$$\begin{aligned}
\mu_{H,t} = \bar{\mu}_D + \frac{\partial a_\phi}{\partial \tau} - \frac{\partial a_\phi}{\partial s} - \frac{\partial b_{\phi,p}}{\partial s}p_t - \frac{\partial b_{\phi,\lambda}}{\partial s}\lambda_{2,t} + \frac{1}{2}b_{\phi,\lambda}(s)^2\sigma_\lambda^2\lambda_{2,t} \\
+ b_{\phi,p}[-p\phi_{BG} + (1-p)\phi_{GB}] + b_{\phi,\lambda}(s)[-\kappa(\lambda_{2,t} - \bar{\lambda}_2)] \\
= \bar{\mu}_D + \frac{\partial a}{\partial \tau} - \frac{\partial a}{\partial s} + b_{\phi,p}\phi_{GB} + b_{\phi,\lambda}(s)\kappa\bar{\lambda}_2 \\
+ \left(-\frac{\partial b_{\phi,p}}{\partial s} - b_{\phi,p}(\phi_{BG} + \phi_{GB})\right)p_t + \left(-\frac{\partial b_{\phi,\lambda}}{\partial s} + \frac{1}{2}b_{\phi,\lambda}(s)^2\sigma_\lambda^2 + \kappa\bar{\lambda}b_{\phi,\lambda}(s)\right)\lambda_{2,t},
\end{aligned} \tag{B.33}$$

$$\begin{aligned}
\sigma_{H,t} &= \left[\sigma, b_{\phi,\lambda}(s)\sigma_\lambda\sqrt{\lambda_{2,t}}\right]^\top \\
\mu_{\pi,t} &= -(\beta + \mu - \gamma\sigma^2) - \bar{\lambda}(p_t)E_\nu\left[e^{(1-\gamma)Z_{1,t}} - 1\right] - \lambda_{2,t}E_\nu\left[e^{(1-\gamma)Z_{2,t}} - 1\right] \\
\sigma_{\pi,t} &= \left[-\gamma\sigma, (1-\gamma)b_\lambda\sigma_\lambda\sqrt{\lambda_{2,t}}\right]^\top.
\end{aligned} \tag{B.34}$$

In addition we have

$$\frac{\bar{\mathcal{J}}_j(H_t\pi_t)}{H_t\pi_t} = E_\nu\left[e^{(\phi-\gamma)Z_{j,t}}-1\right], j=1,2. \tag{B.35}$$

So we end up with the following equation,

$$\begin{aligned}
&\bar{\mu}_D + \frac{\partial a_\phi}{\partial \tau} - \frac{\partial a_\phi}{\partial s} + b_{\phi,p}\phi_{GB} + b_{\phi,\lambda}(s)\kappa\bar{\lambda} \\
&\quad + \left(\frac{\partial b_{\phi,p}}{\partial \tau} - \frac{\partial b_{\phi,p}}{\partial s} - b_{\phi,p}(\phi_{BG}+\phi_{GB})\right)p_t + \left(-\frac{\partial b_{\phi,\lambda}}{\partial s} + \frac{1}{2}b_{\phi,\lambda}(s)^2\sigma_\lambda^2 - \kappa b_{\phi,\lambda}(s)\right)\lambda_{2,t} \\
&\quad - (\beta+\mu-\gamma\sigma^2) - \left[\lambda^G + p_t(\lambda^B-\lambda^G)\right]E_\nu\left[e^{(1-\gamma)Z_{1,t}}-1\right] - \lambda_{2,t}E_\nu\left[e^{(1-\gamma)Z_{2,t}}-1\right] \\
&\qquad\qquad - \gamma\sigma^2 + (1-\gamma)b_\lambda b_{\phi,\lambda}(s)\sigma_\lambda^2\lambda_{2,t} \\
&\qquad + \left[\lambda^G + p(\lambda^B-\lambda^G)\right]E_\nu\left[e^{(\phi-\gamma)Z_{1,t}}-1\right] + \lambda_{2,t}E_\nu\left[e^{(\phi-\gamma)Z_{2,t}}-1\right] = 0.
\end{aligned} \tag{B.36}$$

We first collect the coefficients of p_t, and get

$$\left(-\frac{\partial b_{\phi,p}(s)}{\partial s} - (\phi_{BG}+\phi_{GB})b_{\phi,p}(s)\right) + (\lambda^B-\lambda^G)E_\nu\left[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}}\right] = 0, \tag{B.37}$$

which is equivalent to the following ordinary differential equation,

$$\frac{\partial b_{\phi,p}(s)}{\partial s} = -(\phi_{BG}+\phi_{GB})b_{\phi,p}(s) + (\lambda^B-\lambda^G)E_\nu\left[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}}\right], \tag{B.38}$$

with boundary condition

$$b_{\phi,p}(0) = 0. \tag{B.39}$$

This yields the following closed-form solution to $b_{\phi,p}(s)$:

$$b_{\phi,p}(s) = \frac{(\lambda^B-\lambda^G)E_\nu\left[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}}\right]}{\phi_{BG}+\phi_{GB}}\left(1-e^{-(\phi_{BG}+\phi_{GB})s}\right). \tag{B.40}$$

We next collect the coefficients of $\lambda_{2,t}$, and get

$$-\frac{\partial b_{\phi,\lambda}}{\partial s} + \frac{1}{2}b_{\phi,\lambda}(s)^2\sigma_\lambda^2 - \kappa b_{\phi,\lambda}(s) + (1-\gamma)b_\lambda b_{\phi,\lambda}(s)\sigma_\lambda^2 + E_\nu\left[e^{(\phi-\gamma)Z_{2,t}} - e^{(1-\gamma)Z_{2,t}}\right] = 0. \tag{B.41}$$

So we showed that $b_{\phi,\lambda}(s)$ is the solution to

$$\frac{db_{\phi,\lambda}(s)}{ds} = \frac{1}{2}\sigma_\lambda^2 b_{\phi,\lambda}(s)^2 + \left[(1-\gamma)b_\lambda\sigma_\lambda^2 - \kappa\right]b_{\phi,\lambda}(s) + E_\nu\left[e^{(\phi-\gamma)Z_{2,t}} - e^{(1-\gamma)Z_{2,t}}\right], \tag{B.42}$$

with boundary condition $b_{\phi,\lambda}(0) = 0$.

Finally we solve $a_\phi\big(\tau, s; p_0(t)\big)$.

We collect the remaining terms, and get

$$\frac{\partial a_\phi}{\partial \tau} - \frac{\partial a_\phi}{\partial s} + \bar{\mu}_D + \kappa\bar{\lambda} b_{\phi,\lambda}(s) - \beta - \bar{\mu}_C + \gamma\sigma^2 + \lambda^G E_\nu \left[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}} \right] = 0. \quad \text{(B.43)}$$

This gives us the following partial differential equation of $a_\phi\big(\tau, s; p_0(t)\big)$:

$$\frac{\partial a_\phi}{\partial \tau} - \frac{\partial a_\phi}{\partial s} = \beta + \bar{\mu}_C - \bar{\mu}_D - \lambda^G E_\nu \left[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}} \right] - \kappa\bar{\lambda} b_{\phi,\lambda}(s), \quad \text{(B.44)}$$

with boundary condition

$$a_\phi(\tau, 0; p_0(t)) = 0, \forall \tau, p_0(t). \quad \text{(B.45)}$$

Note that, (B.44) only holds during non-announcement periods.

Then for $s < T - \tau$, or assets that will mature within the current announcement period, we have[10]:

$$a_\phi(\tau, s; p_0(t)) = -s \left\{ \beta + \bar{\mu}_C - \bar{\mu}_D - \lambda^G E_\nu \left[e^{(\phi-\gamma)Z_t} - e^{(1-\gamma)Z_t} \right] \right\} + \kappa\bar{\lambda} \int_0^s b_{\phi,\lambda}(u) du. \quad \text{(B.46)}$$

For $s > T - \tau$, or assets that will experience at least one announcement, and we need to solve the coefficient recursively using the following algorithm:

1. Let $n = \left[\frac{\tau+s}{T}\right]$. Then n is the number of announcements before the maturity of the asset. In addition, compute $s^* = (\tau + s) \bmod T$, which is the time remaining after the last announcement before maturity.

2. Compute

$$\begin{aligned} &a_\phi(0, s^*; 0) = a_\phi(0, s^*; 1) \\ &\quad = -s^* \left\{ \beta + \bar{\mu}_C - \bar{\mu}_D - \lambda^G E_\nu \left[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}} \right] \right\} + \kappa\bar{\lambda} \int_0^{s^*} b_{\phi,\lambda}(u) du. \end{aligned} \quad \text{(B.47)}$$

   They provide the coefficients right after the last announcements before maturity, given the revealed regime.

3. for $k = 0, 1, 2, \ldots, n - 2$, do the following computation:

[10]This is solved using characteristic function of partial differential equations

(a) Solve $a_\phi\left(T^-,(s^*+kT)^-;0\right)$ and $a_\phi\left(T^-,(s^*+kT)^-;1\right)$ by

$$\begin{aligned}
&a_\phi\big(T^-,(s^*+kT)^-;0\big) = \\
&\quad \log\Bigg\{p^G \exp\Big\{(1-\gamma)\big(a(0;1)+b_p\big)+a_\phi(0,s^*+kT;1)+b_{\phi,p}(s^*+kT)\Big\} \\
&\qquad\qquad + (1-p^G)\exp\big\{(1-\gamma)a(0;0)+a_\phi(0,s^*+kT;0)\big\}\Bigg\} \\
&\qquad\qquad\qquad - b_{\phi,p}(s^*+kT)p^G-(1-\gamma)b_p p^G-(1-\gamma)a(T^-;0)
\end{aligned} \tag{B.48}$$

$$\begin{aligned}
&a_\phi\big(T^-,1,(s^*+kT)^-\big) = \\
&\quad \log\Bigg\{p^B \exp\Big\{(1-\gamma)\big(a(0;1)+b_p\big)+a_\phi(0,s^*+kT;1)+b_{\phi,p}(s^*+kT)\Big\} \\
&\qquad\qquad + (1-p^B)\exp\big\{(1-\gamma)a(0;0)+a_\phi(0,s^*+kT;0)\big\}\Bigg\} \\
&\qquad\qquad\qquad - b_{\phi,p}(s^*+kT)p^B-(1-\gamma)b_p p^B-(1-\gamma)a(T^-;1),
\end{aligned} \tag{B.49}$$

which are implied by (B.32). They provide the coefficients right before the $(n-k)^{th}$ announcement the asset experience between t and $t+s$.

(b) Solve $a_\phi\big(0,s^*+(k+1)T;0\big)$ and $a_\phi\big(0,s^*+(k+1)T;1\big)$ by

$$\begin{aligned}
&a_\phi\big(0,s^*+(k+1)T;0\big) = \\
&\quad a_\phi\big(T^-,s^*+kT;0\big) - T\Big\{\beta+\bar{\mu}_C-\bar{\mu}_D-\lambda^G E_\nu\Big[e^{(\phi-\gamma)Z_{1,t}}-e^{(1-\gamma)Z_{1,t}}\Big]\Big\} \\
&\qquad\qquad + \kappa\bar{\lambda}\int_{s^*+kT}^{s^*+(k+1)T} b_{\phi,\lambda}(u)du
\end{aligned} \tag{B.50}$$

$$\begin{aligned}
&a_\phi\big(0,s^*+(k+1)T;1\big) = \\
&\quad a_\phi\big(T^-,s^*+kT;1\big) - T\Big\{\beta+\bar{\mu}_C-\bar{\mu}_D-\lambda^G E_\nu\Big[e^{(\phi-\gamma)Z_{1,t}}-e^{(1-\gamma)Z_{1,t}}\Big]\Big\} \\
&\qquad\qquad + \kappa\bar{\lambda}\int_{s^*+kT}^{s^*+(k+1)T} b_{\phi,\lambda}(u)du.
\end{aligned} \tag{B.51}$$

They provide the coefficients right after the $(n-k-1)^{th}$ announcement.

4. Solve $a_\phi\big(T^-, (s^*+(n-1)T)^-; 0\big)$ and $a_\phi\big(T^-, (s^*+(n-1)T)^-; 1\big)$ by

$$
\begin{aligned}
&a_\phi\left(T^-, (s^*+(n-1)T)^-; 0\right) = \\
&\log\Bigg\{p^G \exp\Big\{(1-\gamma)\big(a(0;1)+b_p\big) + a_\phi(0, s^*+(n-1)T; 1) + b_{\phi,p}(s^*+(n-1)T)\Big\} \\
&\qquad\qquad + (1-p^G)\exp\big\{(1-\gamma)a(0;0) + a_\phi(0, s^*+(n-1)T; 0)\big\}\Bigg\} \\
&\qquad\qquad\qquad - b_{\phi,p}(s^*+(n-1)T)p^G - (1-\gamma)b_p p^G - (1-\gamma)a(T^-;0) \qquad \text{(B.52)}
\end{aligned}
$$

$$
\begin{aligned}
&a_\phi\left(T^-, 1, (s^*+(n-1)T)^-\right) = \\
&\log\Bigg\{p^B \exp\Big\{(1-\gamma)\big(a(0;1)+b_p\big) + a_\phi(0, s^*+(n-1)T; 1) + b_{\phi,p}(s^*+(n-1)T)\Big\} \\
&\qquad\qquad + (1-p^B)\exp\big\{(1-\gamma)a(0;0) + a_\phi(0, s^*+(n-1)T; 0)\big\}\Bigg\} \\
&\qquad\qquad\qquad - b_{\phi,p}(s^*+(n-1)T)p^B - (1-\gamma)b_p p^B - (1-\gamma)a(T^-;1), \qquad \text{(B.53)}
\end{aligned}
$$

They provide the coefficients right before the 1^{st} announcement the asset will experience after t.

5. Finally, solve

$$
\begin{aligned}
&a_\phi\big(\tau, s; 0\big) = \\
&a_\phi\big(T^-, s^*+(n-1)T; 0\big) - (T-\tau)\Big\{\beta + \bar{\mu}_C - \bar{\mu}_D - \lambda^G E_\nu\Big[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}}\Big]\Big\} \\
&\qquad\qquad + \kappa\bar{\lambda}\int_{s^*+(n-1)T}^{s} b_{\phi,\lambda}(u)du \qquad \text{(B.54)}
\end{aligned}
$$

$$
\begin{aligned}
&a_\phi\big(\tau, s; 1\big) = \\
&a_\phi\big(T^-, s^*+(n-1)T; 1\big) - (T-\tau)\Big\{\beta + \bar{\mu}_C - \bar{\mu}_D - \lambda^G E_\nu\Big[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}}\Big]\Big\} \\
&\qquad\qquad + \kappa\bar{\lambda}\int_{s^*+(n-1)T}^{s} b_{\phi,\lambda}(u)du. \qquad \text{(B.55)}
\end{aligned}
$$

Simplifying the algorithm

The algorithm before shows that

$$
\begin{aligned}
a_\phi(0,s^*;0) &= a_\phi(0,s^*;1) \\
&= \int_0^{s^*} \left(-\beta-\mu+\bar{\mu}_D+\lambda^G E_\nu\left[e^{(\phi-\gamma)Z_{1,t}}-e^{(1-\gamma)Z_{1,t}}\right]+\kappa\bar{\lambda}b_{\phi,\lambda}(u)\right)du \qquad \text{(B.56)}
\end{aligned}
$$

To simplify notation, define

$$
g(m,n)=\int_m^n \left(-\beta-\mu+\bar{\mu}_D+\lambda^G E_\nu\left[e^{(\phi-\gamma)Z_{1,t}}-e^{(1-\gamma)Z_{1,t}}\right]+\kappa\bar{\lambda}b_{\phi,\lambda}(u)\right)du, \qquad \text{(B.57)}
$$

Then $a_\phi(0,s^*;0)=a_\phi(0,s^*;1)=g(0,s^*)$. For step 3(a), when $k=0$, we have

$$
\begin{aligned}
a_\phi(T^-(s^*)^-;0) &= \log\left\{p^G e^{(1-\gamma)(a(0;1)+b_p)+g(0,s^*)+b_{\phi,p}(s^*)+}+(1-p^G)e^{(1-\gamma)a(0;0)+g(0,s^*)}\right\} \\
&\quad - b_{\phi,p}(s^*)p^G-(1-\gamma)b_p p^G-(1-\gamma)a(T^-;0) \\
&= g(0,s^*)+\log\left\{p^G e^{(1-\gamma)(a(0;1)+b_p)+b_{\phi,p}(s^*)}+(1-p^G)e^{(1-\gamma)a(0;0)}\right\} \\
&\quad - b_{\phi,p}(s^*)p^G-(1-\gamma)b_p p^G-(1-\gamma)a(T^-;0) \\
a_\phi(T^-,(s^*)^-;1) &= g(0,s^*)+\log\left\{p^B e^{(1-\gamma)(a(0;1)+b_p)+b_{\phi,p}(s^*)}+(1-p^B)e^{(1-\gamma)a(0;0)}\right\} \\
&\quad - b_{\phi,p}(s^*)p^B-(1-\gamma)b_p p^B-(1-\gamma)a(T^-;1)
\end{aligned}
\qquad \text{(B.58)}
$$

It is easy to show that

$$
\begin{aligned}
a_\phi(0,s^*+T;0) &= a_\phi(T^-,(s^*)^-;0)+g(s^*,T+s^*) \\
&= g(0,T+s^*)+\log\left\{p^G e^{(1-\gamma)(a(0;1)+b_p)+b_{\phi,p}(s^*)}+(1-p^G)e^{(1-\gamma)a(0;0)}\right\} \\
&\quad - b_{\phi,p}(s^*)p^G-(1-\gamma)b_p p^G-(1-\gamma)a(T^-;0) \\
a_\phi(0,s^*+T;1) &= a_\phi(T^-,(s^*)^-;1)+g(s^*,T+s^*) \\
&= g(0,T+s^*)+\log\left\{p^B e^{(1-\gamma)(a(0;1)+b_p)+b_{\phi,p}(s^*)}+(1-p^B)e^{(1-\gamma)a(0;0)}\right\} \\
&\quad - b_{\phi,p}(s^*)p^B-(1-\gamma)b_p p^B-(1-\gamma)a(T^-;1)
\end{aligned}
\qquad \text{(B.59)}
$$

Repeat the steps above, we can come up with the following simplified algorithm

1. Let $n=\left[\frac{\tau+s}{T}\right]$. Then n is the number of announcements before the maturity of the asset. In addition, compute $s^*=(\tau+s) \bmod T$, which is the time remaining after the last announcement before maturity.

2. Recursively define the following function $h(k,\tau,s;p)$, $p=0,1$.

(a) $h(0,\tau,s;0) = h(0,\tau,s;1) = 0$;

(b) For $k = 1,2,3,\dots,n$

$$\begin{aligned}
h(k,\tau,s;0) = \log\Big\{&p^G \exp^{(1-\gamma)(a(0;1)+b_p)+h(k-1,\tau,s;1)+b_{\phi,p}\left(s^*+(k-1)T\right)} \\
&+ (1-p^G)\exp^{(1-\gamma)a(0;0)+h(k-1,\tau,s;0)}\Big\} \\
&\quad - b_{\phi,p}\big(s^*+(k-1)T\big)p^G - (1-\gamma)b_p p^G - (1-\gamma)a(T^-;0) \\
h(k,\tau,s;1) = \log\Big\{&p^B \exp^{(1-\gamma)(a(0;1)+b_p)+h(k-1,\tau,s;1)+b_{\phi,p}\left(s^*+(k-1)T\right)} \\
&+ (1-p^B)\exp^{+b_p a(0;0)+h(k-1,\tau,s;0)}\Big\} \\
&\quad - b_{\phi,p}\big(s^*+(k-1)T\big)p^B - (1-\gamma)b_p p^B - (1-\gamma)a(T^-;1)
\end{aligned} \tag{B.60}$$

3. Then

$$\begin{aligned}
a(\tau,s;0) &= h(n,\tau,s;0) + g(0,s) \\
&= h(n,\tau,s;0) + \int_0^s \Big(-\beta - \mu + \bar{\mu}_D + \lambda^G E_\nu\Big[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}}\Big] + \kappa\bar{\lambda}b_{\phi,\lambda}(u)\Big)\,du \\
a(\tau,s;1) &= h(n,\tau,s;1) + g(0,s) \\
&= h(n,\tau,s;1) + \int_0^s \Big(-\beta - \mu + \bar{\mu}_D + \lambda^G E_\nu\Big[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}}\Big] + \kappa\bar{\lambda}b_{\phi,\lambda}(u)\Big)\,du
\end{aligned} \tag{B.61}$$

□

Proof of Theorem 3. By non-arbitrage, the price of the stream of dividends, $F_\phi(D_t, p_t, p_0(t), \lambda_{2,t}, \tau)$, is

$$\begin{aligned}
F_\phi(D_t, p_t, p_0(t), \lambda_{2,t}, \tau) &= \int_0^\infty H(D_t, p_t, p_0(t), \lambda_{2,t}, \tau, s)ds \\
&= \int_0^\infty D_t \exp\Big\{a_\phi^k\big(\tau,s;p_0(t)\big) + b_{\phi,p}^k(s)p_t + b_{\phi,\lambda}^k(s)\lambda_{2,t}\Big\}\,ds \\
&= D_t \int_0^\infty \exp\Big\{a_\phi^k\big(\tau,s;p_0(t)\big) + b_{\phi,p}^k(s)p_t + b_{\phi,\lambda}^k(s)\lambda_{2,t}\Big\}\,ds
\end{aligned} \tag{B.62}$$

Let $G_\phi(p_t, p_0(t), \lambda_{2,t}, \tau)$ be the price-dividend ratio of the asset. Then

$$G_\phi(p_t, p_0(t), \lambda_{2,t}, \tau) = \int_0^\infty \exp\Big\{a_\phi^k\big(\tau,s;p_0(t)\big) + b_{\phi,p}^k(s)p_t + b_{\phi,\lambda}^k(s)\lambda_{2,t}\Big\}\,ds. \tag{B.63}$$

We then can write

$$F_\phi(D_t, p_t, p_0(t), \lambda_{2,t}, \tau) = D_t G_\phi(p_t, p_0(t), \lambda_{2,t}, \tau). \tag{B.64}$$

By Ito's Lemma, we must have

$$\sigma_{F,t} = \left[\sigma, \frac{1}{G_t}\frac{\partial G_t}{\partial \lambda_t}\sigma_\lambda\sqrt{\lambda_{2,t}}\right]^\top, \tag{B.65}$$

where $G_t = G_\phi(p_t, p_0(t), \lambda_{2,t}, \tau)$.

As a result, with Lemma B.3 the premium of the asset is

$$\begin{aligned} r_t^\phi - r_t =& \gamma\sigma^2 - \lambda_{2,t}(1-\gamma)\frac{1}{G_t}\frac{\partial G_t}{\partial \lambda}b_\lambda\sigma_\lambda^2 \\ & - \bar{\lambda}(p_t)E_\nu\left[\left(e^{-\gamma Z_{1,t}}-1\right)\left(e^{\phi Z_{1,t}}-1\right)\right] - \lambda_{2,t}E_\nu\left[\left(e^{-\gamma Z_{2,t}}-1\right)\left(e^{\phi Z_{2,t}}-1\right)\right] \end{aligned} \tag{B.66}$$

□

B.5 The announcement premium

Lemma B.5. *Suppose that after the announcement, the asset's price is given by* $\exp(q_0 + b_\lambda^*\lambda_{2,t}) > \exp(q_1 + b_\lambda^*\lambda_{2,t})$*, conditioning on that the announcement reveals good or bad state, respectively, then the pre-announcement price of the asset is higher if the previous announcement revealed good state.*

Proof. Without loss of generality, let $\exp(h^G + b_\lambda^*\lambda_{2,t^-})$ and $\exp(h^B + b_\lambda^*\lambda_{2,t^-})$ be the prices of the asset right before the announcement, conditioning on that the previous announcement revealed good or bad state, respectively.

We want to show that $h^G > h^B$.

Euler equation implies that

$$\begin{aligned} &\exp\left\{h^G + (1-\gamma)a(T;0) + (1-\gamma)b_p p^G\right\} \\ &\qquad = p^G\exp\left\{q_1 + (1-\gamma)a(0;1) + (1-\gamma)b_p\right\} + (1-p^G)\exp\left\{q_0 + (1-\gamma)a(0;0)\right\} \end{aligned}$$

$$\begin{aligned} &\exp\left\{h^B + (1-\gamma)a(T;1) + (1-\gamma))b_p p^B\right\} \\ &\qquad = p^B\exp\left\{q_1 + (1-\gamma)a(0;1) + (1-\gamma)b_p\right\} + (1-p^B)\exp\left\{q_0 + (1-\gamma)a(0;0)\right\}. \end{aligned}$$

This means that

$$
\begin{aligned}
&h^G - h^B + (1-\gamma)\left[a(T;0) + b_p p^G - a(T;1) - b_p p^B\right] \\
&\qquad = \log\left\{\frac{p^G + (1-p^G)\exp\big(q_0 - q_1 + (1-\gamma)\big(a(0;0) - a(0;1) - b_p\big)\big)}{p^B + (1-p^B)\exp\big(q_0 - q_1 + (1-\gamma)\big(a(0;0) - a(0;1) - b_p\big)\big)}\right\}. \qquad \text{(B.67)}
\end{aligned}
$$

As $0 < p^G < p^B < 1$, or $0 < 1 - p^B < 1 - p^G < 1$, the right hand side of (B.67) is increasing in $q_0 - q_1$.

Note that when $q_1 = q_0$, plugging in the continuity condition of the representative agent's value function, we can obtain $h^G = h^B$. This implies that

$$
h^G - h^B + (1-\gamma)\left[a(T;0) + b_p p^G - a(T;1) - b_p p^B\right] > (1-\gamma)\left[a(T;0) + b_p p^G - a(T;1) - b_p p^B\right],
$$

when $q_0 > q_1$.

As a result $h^G > h^B$. □

Lemma B.6. *Upon announcements, or when $t \bmod T = 0$, if $\phi > 1$, given $\lambda_{2,t}$, if the price of a zero coupon asset with maturity at $t+s$ is higher when the most recent announcement revealed good state, then at time $t - T$, right after the announcement, the price is lower if the announcement revealed a good state. In other words*

$$
\begin{aligned}
&H(D_{t^-}, p(T^-, 0), 0, \lambda_{2,t}, T^-, s^+) > H(D_{t^-}, p(T^-, 1), 1, \lambda_{2,t}, T^-, s^+) \\
&\qquad \Rightarrow H(D_{t-T}, 0, 0, \lambda_{2,t-T}, 0, s+T) > H(D_{t-T}, 1, 1, \lambda_{2,t-T}, 0, s+T), \qquad \text{(B.68)}
\end{aligned}
$$

for H given in Lemma B.4.

Proof. We have

$$
\begin{aligned}
&H(D_{t^-}, p(T^-, 0), 0, \lambda_{2,t}, T^-, s^+) > H(D_{t^-}, p(T^-, 1), 1, \lambda_{2,t}, T^-, s^+) \\
&\qquad \Rightarrow a_\phi(T^-, s; 0) + b_{\phi,p}(s) p^G > a_\phi(T^-, s; 1) + b_{\phi,p}(s) p^B.
\end{aligned}
$$

We want to show

$$
a_\phi(0, s+T; 0) > a_\phi(0, s+T; 1) + b_{\phi,p}(s+T).
$$

We know that

$$a_\phi(0,s+T;0) = a_\phi(T^-,s;0) + \int_s^{s+T} \left(-\beta - \bar{\mu}_C + \bar{\mu}_D + \lambda^G E_\nu\left[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}}\right] + \kappa\bar{\lambda} b_{\phi,\lambda}(u)\right) du$$
$$a_\phi(0,s+T;1) = a_\phi(T^-,s;1) + \int_s^{s+T} \left(-\beta - \bar{\mu}_C + \bar{\mu}_D + \lambda^G E_\nu\left[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}}\right] + \kappa\bar{\lambda} b_{\phi,\lambda}(u)\right) du \tag{B.69}$$

In addition, as $b_{\phi,p}(S) < 0$ when $\phi > 1$, we have

$$\begin{aligned} a_\phi(0,s+T;0) &= a_\phi(T^-,s;0) + \int_s^{s+T} \left(-\beta - \bar{\mu}_C + \bar{\mu}_D + \lambda^G E_\nu\left[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}}\right] + \kappa\bar{\lambda} b_{\phi,\lambda}(u)\right) du \\ &= a_\phi(T^-,s;0) + g(s,s+T) \\ &> a_\phi(T^-,s;0) + b_{\phi,p}(s)p^G + g(s,s+T) > a_\phi(T^-,s;1) + b_{\phi,p}(s)p^B + g(s,s+T) \\ &= a_\phi(0,s+T;1) + b_{\phi,p}(s)p^B, \end{aligned} \tag{B.70}$$

where $g(m,n)$ is as defined before.

In addition, define $\bar{p} = \frac{\phi_{GB}}{\phi_{GB}+\phi_{BG}}$, or the stationary probability of bad state, we know that

$$b_{\phi,p}(s)p^B = \frac{(\lambda^B - \lambda^G)E_\nu\left[e^{(\phi-\gamma)Z_{1,t}} - e^{(1-\gamma)Z_{1,t}}\right]}{\phi_{BG}+\phi_{GB}} \left(1 - e^{-(\phi_{BG}+\phi_{GB})s}\right) \times \left(\bar{p} + (1-\bar{p})e^{-(\phi_{GB}+\phi_{BG})T}\right). \tag{B.71}$$

Note that

$$\begin{aligned} &\left(1 - e^{-(\phi_{BG}+\phi_{GB})s}\right) \times \left(\bar{p} + (1-\bar{p})e^{-(\phi_{GB}+\phi_{BG})T}\right) < 1 - e^{-(\phi_{BG}+\phi_{GB})(s+T)} \\ \Longleftrightarrow & \bar{p} - (1-\bar{p})e^{-(\phi_{BG}+\phi_{GB})(s+T)} - \bar{p}e^{-(\phi_{BG}+\phi_{GB})s} + (1-\bar{p})e^{-(\phi_{BG}+\phi_{GB})T} < 1 - e^{-(\phi_{BG}+\phi_{GB})(s+T)} \\ \Longleftrightarrow & 1 - \bar{p} > \bar{p}e^{-(\phi_{BG}+\phi_{GB})(s+T)} - \bar{p}e^{-(\phi_{BG}+\phi_{GB})s} + (1-\bar{p})e^{-(\phi_{BG}+\phi_{GB})T}. \end{aligned}$$

Obviously

$$\begin{aligned} 1 - \bar{p} &> (1-\bar{p})e^{-(\phi_{BG}+\phi_{GB})T} \\ 0 &> \bar{p}e^{-(\phi_{BG}+\phi_{GB})(s+T)} - \bar{p}e^{-(\phi_{BG}+\phi_{GB})s}, \end{aligned}$$

which means that

$$1 - \bar{p} > \bar{p}e^{-(\phi_{BG}+\phi_{GB})(s+T)} - \bar{p}e^{-(\phi_{BG}+\phi_{GB})s} + (1-\bar{p})e^{-(\phi_{BG}+\phi_{GB})T}$$

always holds. This implies that

$$b_{\phi,p}(s)p^B > b_{\phi,p}(s+T) \times 1, \text{ if } \phi > 1.$$

As a result,

$$a_\phi(0, s+T; 0) > a_\phi(0, s+T; 1) + b_{\phi,p}(s+T). \tag{B.72}$$

$\square$

Proof of Theorem 4. By applying the formula of $a_\phi(\tau, s; p_0(t))$, we know at time t^- such that $t \bmod T = 0$, that the time-t price of of D_{t+s} will be negatively correlated with the state price density, when $\phi > 1$. As a result, by Euler Equation, the announcement premium for zero-coupon dividend assets must be positive.

Then the announcement premium for the equity will be a weight-average of the premium for zero-coupon dividend claims, which then must be positive as well. $\square$

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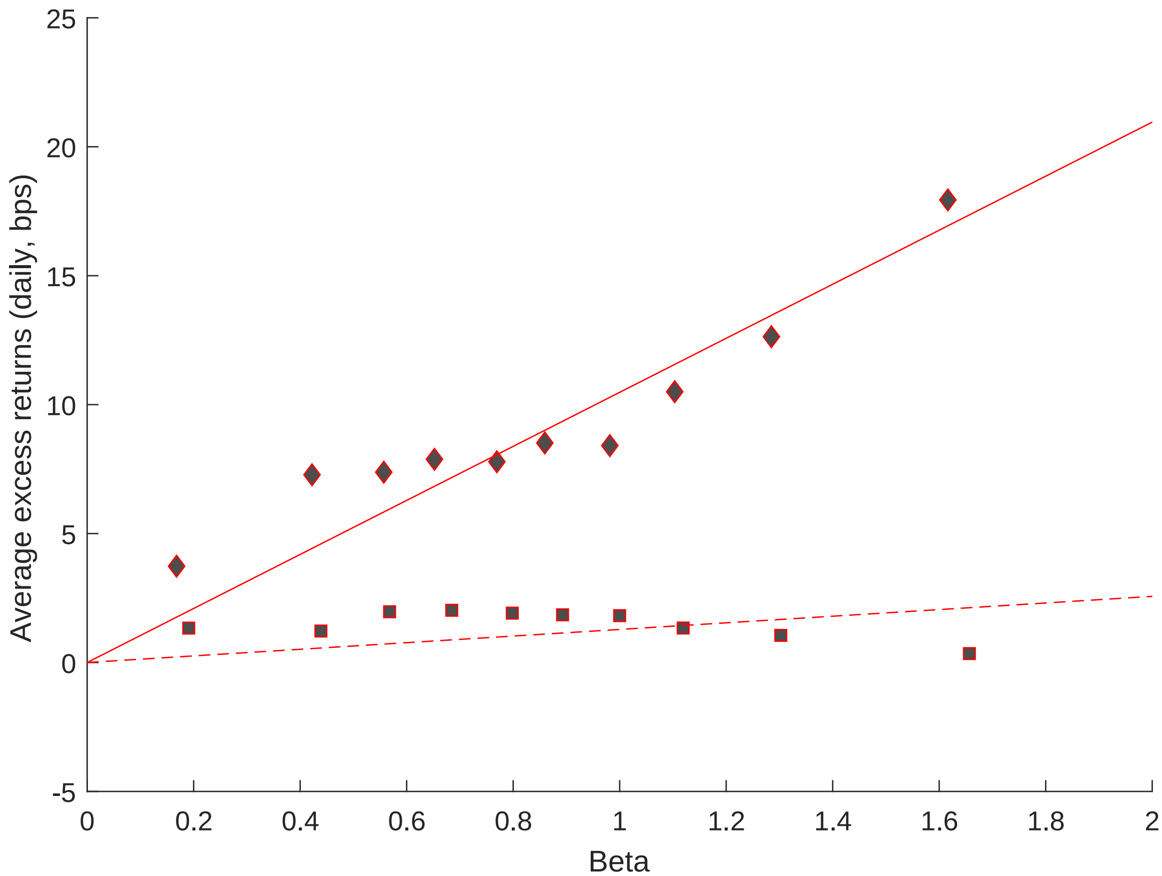
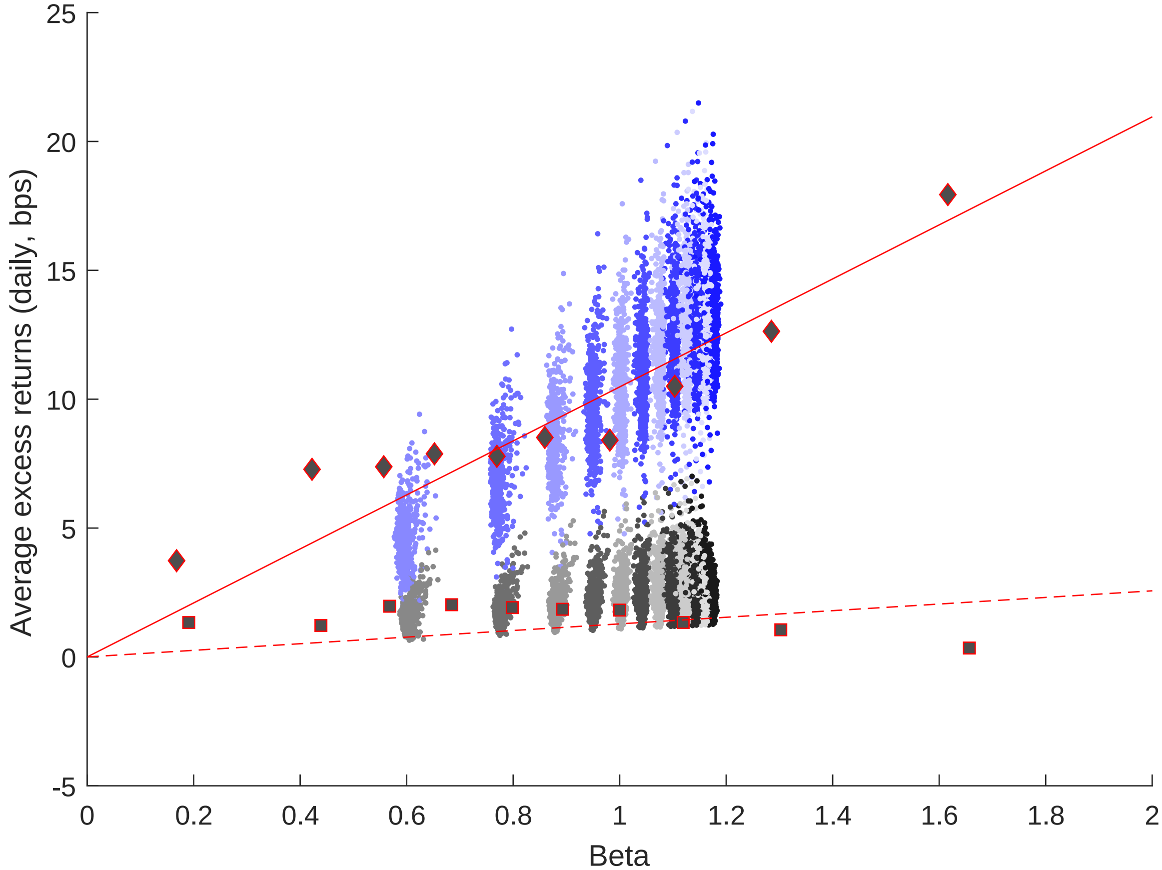
List of Figures

Figure 1: Portfolio excess returns against CAPM betas on announcement and non-announcement days, data only



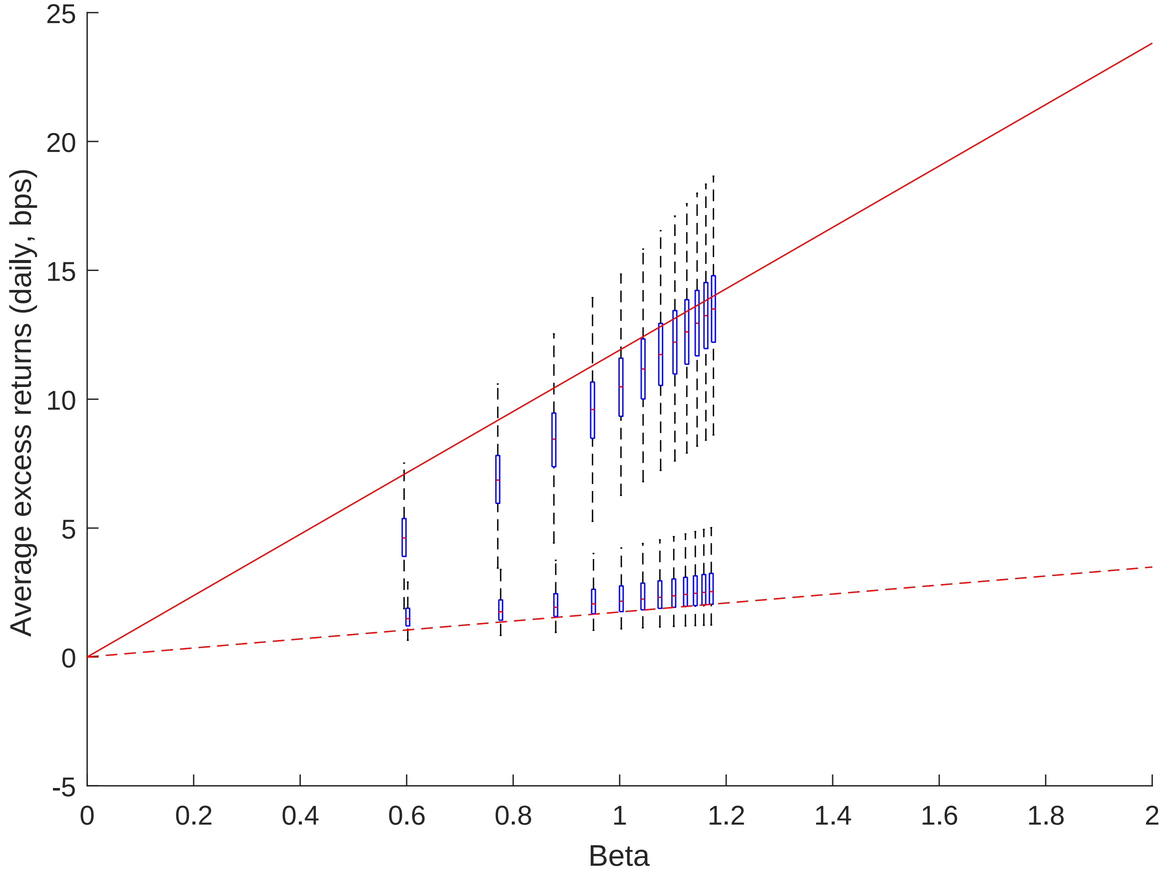
Notes: The figure shows average excess returns on announcement days (diamonds) and non-announcement days (squares) on beta-sorted portfolios in daily data from 1961.01-2016.09 as a function of the CAPM beta. Also shown are estimated regression lines for announcement day returns against beta (solid red) and non-announcement day returns against beta (dashed red).

Figure 2: Portfolio excess returns against CAPM betas on announcement and non-announcement days



Notes: The figure shows average excess returns on announcement days (diamonds) and non-announcement days (squares) on beta-sorted portfolios in daily data from 1961.01-2016.09 as a function of the CAPM beta. Also shown are estimated regression lines for announcement day returns against beta (solid red) and non-announcement day returns against beta (dashed red). We simulate 500 samples of artificial data from the model, each containing a cross-section of firms. The blue and grey dots show average announcement day and non-announcement day returns for each sample as a function of beta, respectively.

Figure 3: Boxplots of simulated portfolio average excess returns on announcement and non-announcement days



Notes: We compute average excess returns on announcement and non-announcement days for a cross-section of assets in data simulated from the model. The red line shows the median for each portfolio across samples; the box corresponds to the interquartile range (IQR), and the whiskers correspond to the highest and lowest data value within $1.5 \times$ IQR of the highest and lowest quartile. We plot returns against the median CAPM beta across samples for each portfolio. The red solid and dashed lines are the empirical regression lines of portfolio mean excess returns against market beta on announcement and non-announcement days, respectively.

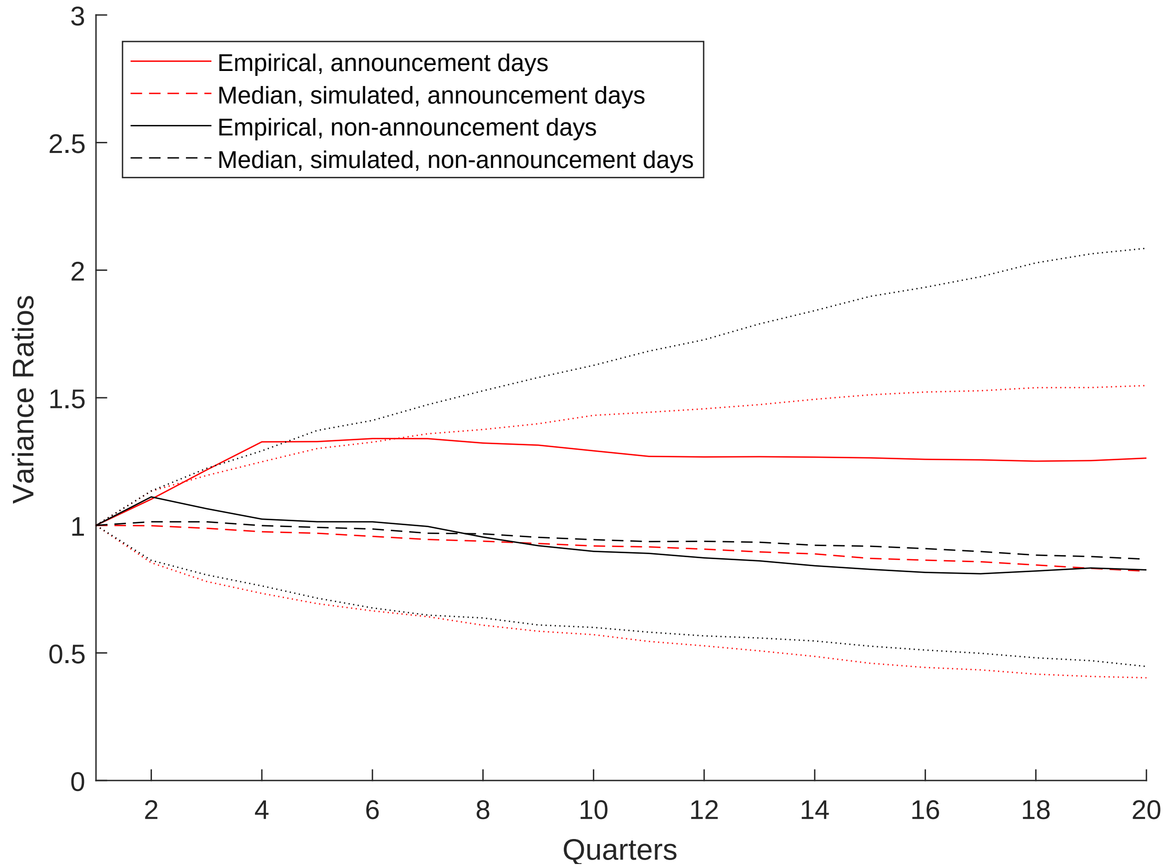


Figure 4: Variance ratios for market portfolio of announcement and non-announcement day returns

This figure shows empirical quarterly variance ratios of the market portfolio return and 90% confidence interval constructed using simulation data generated from the model. The quarterly announcement (non-announcement) day excess returns are computed as the sum of log daily excess returns on announcement (non-announcement) days in each calendar quarter. Then we compute the cumulative excess returns of multiple quarters with overlapping windows of length k quarters ($k \geq 1$). The cumulative excess returns are then used to compute the sample variances and construct the quarterly variance ratios. The variance here are computed using sample variances (demeaned).

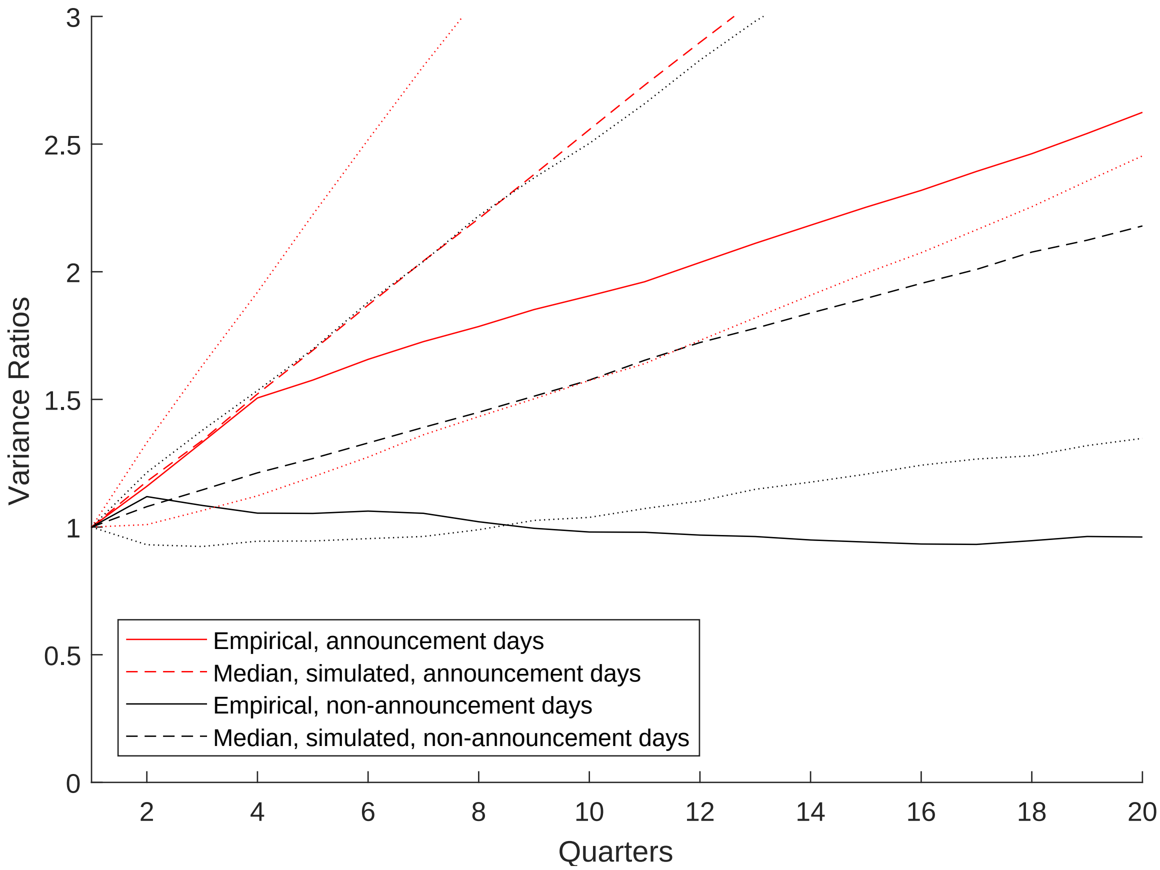


Figure 5: Variance ratios for market portfolio of announcement and non-announcement day returns: mean squared returns as estimates

This figure shows empirical quarterly variance ratios of the market portfolio return and 90% confidence interval constructed using simulation data generated from the model. The quarterly announcement (non-announcement) day excess returns are computed as the sum of log daily excess returns on announcement (non-announcement) days in each calendar quarter. Then we compute the cumulative excess returns of multiple quarters with overlapping windows of length k quarters ($k \geq 1$). The cumulative excess returns are then used to compute the sample variances and construct the quarterly variance ratios. The variance here are computed using squared returns (un-demeaned).

List of Tables

Table 1: Summary statistics of the excess returns of 10 beta-sorted portfolios

	Unconditional			Announcement day			Non-announcement day		
k	$E[RX^k]$	σ^k	β^k	$E[RX^k]$	σ^k	β^k	$E[RX^k]$	σ^k	β^k
1	1.61	53.3	0.19	3.73	53.3	0.17	1.34	53.3	0.19
2	1.91	59.4	0.44	7.28	59.2	0.42	1.22	59.4	0.44
3	2.58	68.9	0.57	7.38	70.1	0.56	1.97	68.8	0.57
4	2.69	77.6	0.68	7.88	77.1	0.65	2.03	77.6	0.68
5	2.58	87.5	0.79	7.78	87.7	0.77	1.91	87.4	0.80
6	2.61	95.5	0.89	8.51	96.0	0.86	1.85	95.5	0.89
7	2.57	106.0	1.00	8.41	108.1	0.98	1.82	105.7	1.00
8	2.38	118.0	1.12	10.50	120.4	1.10	1.34	117.6	1.12
9	2.37	136.8	1.30	12.63	139.5	1.29	1.05	136.4	1.30
10	2.35	176.6	1.65	17.94	177.7	1.62	0.35	176.3	1.66

Note: Sample statistics for excess returns of ten beta-sorted portfolios. The sample period is 1961.01-2016.09. We show the sample mean excess returns ($E[RX^k]$), standard deviation (σ^k) and CAPM beta (β^k). Each portfolio is labelled by k. Column 1-3 report estimates with all data available. Column 4-6 and column 7-9 use returns on announcement and non-announcement days, respectively. The unit is bps per day.

Table 2: Calibration and simulation parameters

Panel A: Basic parameters												
Average log growth in consumption $\bar{\mu}_C(\%)$	2.54											
Average log growth in dividend $\bar{\mu}_D(\%)$	2.92											
Volatility of consumption growth $\sigma(\%)$	2											
Rate of time preference β	0.012											
Relative risk aversion γ	3											
Panel B: Rare event (disaster) parameters												
Probability of disaster in good state λ^G	0											
Probability of disaster in bad state $\lambda^G(\%)$	5.44											
Probability of switching to bad state ϕ_{GB}	0.05											
Probability of switching to good state ϕ_{BG}	0.33											
Average probability of disaster (Sector 2)$\bar{\lambda}(\%)$	2.84											
Mean reversion in disaster probability κ	0.08											
Volatility for disaster probability σ_λ	0.0670											
Panel C: Simulation parameters												
Number of finite samples	500											
Number of firms	12											
Number of periods in each period (years)	100											
Burn-in period length (years)	50											
Length of each announcement non-announcement cycle (T)	1/24											
Panel D: ϕ_k, the loading of individual portfolio k on disasters												
k	1	2	3	4	5	6	7	8	9	10	11	12
ϕ_k	1.5	2	2.5	3	3.5	4	4.5	5	5.5	6	6.5	7

Note: Parameter values for the main calibration, expressed in annual terms.

Table 3: Empirical values and simulated distributions of regression slope coefficient of excess returns on portfolio betas on announcement and non-announcement days.

Coefficient	Data		Simulation	
	Beta-sorted portfolios	All portfolios	Median	90 % CI
δ_a	10.47	11.92	10.77	$[8.12, 13.88]$
δ_n	1.28	1.74	2.17	$[1.31, 3.95]$
$\delta_a - \delta_n$	9.19	10.17	8.55	$[5.47, 11.55]$

Note: For each sample, the regression $E[RX_t^k \mid t \in i] = \delta_i \beta_i^k + \eta_i^k$ is estimated, where $i = \mathcal{A}, \mathcal{N}$ stands for sets of accouncement and non-announcement days, respectively. k stands for different portfolios. (Beta-sorted or Fama-French three factor / industry portfolios in data, or simulated beta-sorted portfolios.) The first two columns reports the regression coefficients in empirical analysis, using beta-sorted portfolios only or including Fama-French 25 and industry portfolios as well. The 90% confidence intervals are computed using simulation samples.

Table 4: Median of mean excess return, volatility and market beta for the twelve simulated portfolios on announcement and non-announcement days

	Unconditional			Announcement day			Non-announcement day		
k	$E[RX^k]$	σ^k	β^k	$E[RX^k]$	σ^k	β^k	$E[RX^k]$	σ^k	β^k
1	1.83	34.43	0.60	4.62	34.18	0.60	1.49	34.39	0.60
2	2.29	44.07	0.78	6.86	43.71	0.78	1.75	43.96	0.78
3	2.60	49.97	0.88	8.45	49.55	0.88	1.93	49.81	0.88
4	2.83	54.05	0.95	9.60	53.46	0.95	2.06	53.86	0.95
5	3.01	56.95	1.00	10.48	56.40	1.00	2.16	56.85	1.00
6	3.16	59.26	1.04	11.17	58.69	1.04	2.25	59.09	1.04
7	3.28	61.06	1.08	11.73	60.46	1.08	2.32	60.94	1.08
8	3.38	62.51	1.10	12.22	61.97	1.10	2.37	62.42	1.10
9	3.46	63.69	1.12	12.61	63.23	1.12	2.43	63.66	1.12
10	3.53	64.71	1.14	12.95	64.30	1.14	2.47	64.67	1.14
11	3.59	65.61	1.16	13.24	65.22	1.16	2.50	65.56	1.16
12	3.64	66.40	1.17	13.50	66.02	1.17	2.54	66.34	1.17

Note: For each sample, market mean excess returns on all trading days, announcement and non-announcement days and are computed, respectively. The market is defined as the value-weighted average of portfolios. This table reports the median of the corresponding statistics across simulation samples.

Table 5: Distribution of simulated difference in mean excess returns on announcement and non-announcement days

Portfolio	Quantiles				
k	10%	25%	50%	75%	90%
1	1.75	2.35	3.13	3.75	4.46
2	3.32	4.14	5.12	5.92	6.77
3	4.45	5.39	6.50	7.39	8.35
4	5.28	6.31	7.50	8.45	9.50
5	5.94	7.01	8.28	9.27	10.38
6	6.45	7.60	8.88	9.91	11.08
7	6.86	8.06	9.39	10.44	11.64
8	7.20	8.45	9.79	10.89	12.11
9	7.48	8.77	10.15	11.27	12.51
10	7.73	9.04	10.45	11.59	12.84
11	7.94	9.29	10.70	11.86	13.12
12	8.13	9.50	10.91	12.10	13.36

Note: This table reports the simulated distribution of finite sample difference in mean excess returns on announcement and non-announcement days. The unit is bps per day.

Table 6: Empirical values and simulated distributions of market excess return and volatility on announcement and non-announcement days

	Data	Simulation	
Statistic	Estimate	Median	90 % CI
$E[RX_t^{\text{mkt}} \mid \mathcal{A}]$	10.66	10.65	$[7.97, 13.78]$
$\text{std}[RX_t^{\text{mkt}} \mid \mathcal{A}]$	102.2	56.4	$[40.7, 75.1]$
$E[RX_t^{\text{mkt}} \mid \mathcal{N}]$	1.27	2.18	$[1.31, 3.95]$
$\text{std}[RX_t^{\text{mkt}} \mid \mathcal{N}]$	98.3	56.7	$[41.1, 74.6]$
$E[RX_t^{\text{mkt}} \mid \mathcal{A}] - E[RX_t^{\text{mkt}} \mid \mathcal{N}]$	9.39	8.42	$[5.34, 11.44]$
$\text{std}[RX_t^{\text{mkt}} \mid \mathcal{A}] - \text{std}[RX_t^{\text{mkt}} \mid \mathcal{N}]$	3.9	-0.1	$[-2.7, 2.3]$

Note: For each sample, $E[RX_t^{\text{mkt}} \mid i]$ and $\text{std}[RX_t^{\text{mkt}} \mid i]$ for market portoflio are computed. $i = \mathcal{A}, \mathcal{N}$ stands for announcement and non-announcement days, respectively. The first column reports the empirical estimates, while the quantiles are computed using simulation samples. The unit is bps per day.

Table 7: Variance ratio of quarterly excess returnson announcement and non-announcement days

Quarter	Announcement days			Non-announcement days		
	Empirical	Median	90% CI	Empirical	Median	90% CI
1	1.00	1.00	[1.00, 1.00]	1.00	1.00	[1.00, 1.00]
2	1.10	0.85	[1.00, 1.13]	1.11	0.86	[1.01, 1.13]
3	1.22	0.78	[0.99, 1.20]	1.07	0.81	[1.01, 1.22]
4	1.33	0.73	[0.97, 1.25]	1.02	0.76	[1.00, 1.29]
5	1.33	0.69	[0.97, 1.30]	1.01	0.71	[0.99, 1.37]
6	1.34	0.66	[0.96, 1.33]	1.01	0.68	[0.99, 1.41]
7	1.34	0.64	[0.94, 1.36]	1.00	0.65	[0.97, 1.47]
8	1.32	0.61	[0.94, 1.38]	0.95	0.64	[0.97, 1.53]
9	1.31	0.59	[0.93, 1.40]	0.92	0.61	[0.95, 1.58]
10	1.29	0.57	[0.92, 1.43]	0.90	0.60	[0.94, 1.63]
11	1.27	0.55	[0.92, 1.44]	0.89	0.58	[0.94, 1.68]
12	1.27	0.53	[0.91, 1.46]	0.87	0.57	[0.94, 1.73]
13	1.27	0.51	[0.90, 1.47]	0.86	0.56	[0.93, 1.79]
14	1.27	0.49	[0.89, 1.49]	0.84	0.55	[0.92, 1.84]
15	1.26	0.46	[0.87, 1.51]	0.83	0.53	[0.92, 1.90]
16	1.26	0.44	[0.86, 1.52]	0.82	0.51	[0.91, 1.93]
17	1.26	0.43	[0.86, 1.53]	0.81	0.50	[0.90, 1.97]
18	1.25	0.42	[0.84, 1.54]	0.82	0.48	[0.88, 2.03]
19	1.25	0.41	[0.83, 1.54]	0.83	0.47	[0.88, 2.06]
20	1.26	0.40	[0.82, 1.55]	0.83	0.45	[0.87, 2.09]

Table 8: Variance ratio of quarterly excess returns: mean squared return as estimateson announcement and non-announcement days

Quarter	Announcement days			Non-announcement days		
	Empirical	Median	90% CI	Empirical	Median	90% CI
1	1.00	1.00	[1.00, 1.00]	1.00	1.00	[1.00, 1.00]
2	1.16	1.18	[1.01, 1.33]	1.12	1.08	[0.93, 1.21]
3	1.33	1.34	[1.06, 1.63]	1.08	1.15	[0.92, 1.38]
4	1.51	1.52	[1.12, 1.92]	1.05	1.21	[0.94, 1.53]
5	1.58	1.69	[1.20, 2.22]	1.05	1.27	[0.95, 1.70]
6	1.66	1.87	[1.27, 2.52]	1.06	1.33	[0.95, 1.88]
7	1.73	2.04	[1.36, 2.81]	1.05	1.39	[0.96, 2.04]
8	1.79	2.21	[1.43, 3.08]	1.02	1.45	[0.99, 2.22]
9	1.85	2.38	[1.50, 3.35]	1.00	1.51	[1.03, 2.37]
10	1.91	2.56	[1.57, 3.66]	0.98	1.58	[1.04, 2.50]
11	1.96	2.73	[1.64, 3.97]	0.98	1.65	[1.07, 2.66]
12	2.04	2.90	[1.73, 4.26]	0.97	1.72	[1.10, 2.83]
13	2.11	3.06	[1.82, 4.55]	0.96	1.78	[1.15, 2.98]
14	2.18	3.22	[1.91, 4.85]	0.95	1.84	[1.18, 3.11]
15	2.25	3.39	[1.99, 5.14]	0.94	1.90	[1.21, 3.24]
16	2.32	3.59	[2.07, 5.43]	0.93	1.95	[1.24, 3.39]
17	2.39	3.77	[2.16, 5.73]	0.93	2.01	[1.27, 3.56]
18	2.46	3.95	[2.25, 6.03]	0.95	2.08	[1.28, 3.74]
19	2.54	4.11	[2.36, 6.33]	0.96	2.12	[1.32, 3.91]
20	2.62	4.27	[2.45, 6.63]	0.96	2.18	[1.35, 4.07]