A Model of the Macroeconomic Announcement Premium with Production

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Empirically, a large fraction of the market equity premium is realized on days with significant macroeconomic announcements, such as the FOMC announcements and the unemployment report. This paper presents a theory and a quantitative model for the macroeconomic announcement premium. Our model accounts for several stylized facts related to the macroeconomic announcement premium: the large equity premium realized upon announcements, the fit of CAPM model on announcement days, and the upward sloping bond announcement premium across maturities. We show that generalized risk sensitivity in preferences is key to generate announcement premiums, and our result holds in both endowment economies as well as production economies.

JEL Code: D81, G12

Key words: announcement premium, generalized risk sensitivity, production

1   Introduction

Macroeconomic announcement days play a central role in the compensation for risks on financial markets. During the period of 1961-2014, about 55% of the market equity premium is realized on about 30 days per year with significant macroeconomic announcements. In the cross-section, the expected return-β relationship predicted by the Capital Asset Pricing Model (CAPM) is strong and significant on macroeconomic announcement days. In addition, bond risk premium is also significant on announcement days and monotonically increasing with respect to maturity.

In this paper, we present a quantitative model to account for the macroeconomic announcement premium. Our model builds on the previous work of Ai and Bansal (forthcoming) who demonstrate that, in endowment economies, generalized risk sensitivity is necessary and sufficient for macroeconomic announcement premium. Intertemporal preferences can in general be represented by the recursive relationship

$$V_t = u\left(C_t\right) + \beta \mathcal{I}\left[V_{t+1}\right],$$

where u is the Von Neumann–Morgenstern utility and $\mathcal{I}$ is the certainty equivalent functional. Ai and Bansal (forthcoming) show that the macro announcement premium cannot be compensation for risk aversion as captured by the concavity in $u\left(\cdot\right)$ in expected utility models and must be compensation for generalized risk sensitivity, which comes from the non-linearity of $\mathcal{I}$.

In this paper, we extend the Ai and Bansal (forthcoming) result to production economies and develop an asset pricing model where the representative agent has a recursive preference that satisfies generalized risk sensitivity and periodically receives macroeconomic announcement that carry news about future economic growth. Positive news about future raises the equity market valuation. At the same time, generalized risk sensitivity implies that the marginal utility of the representative agent decreases with news about future continuation utility. The negative comovement of marginal utility and equity market valuation upon announcements result in a significant equity premium associated on announcement days.

The significant generalized risk sensitivity in preferences in our model implies that the market price of risk is substantially higher on announcement days than non-announcement days and provides a natural explanation for the success of the expected return-β relationship on announcement days. The slope of the security market line, that is, the slope of expected return with respect to β is the market equity premium. Because the market equity premium

is much higher on announcement days, CAPM regressions produce a significant expected return-β relationship on announcement days. On the other hand, because the market equity premium is close to zero on non-announcement days, the expected return-β relationship is insignificant on non-announcement days.

Incorporating inflation riks as in Piazzesi and Schneider (2006) and Bansal and Shaliastovich (2013), our model can also produce a significant bond announcement premium and an upward sloping term structure of bond announcement premium. In our model, inflation is negatively correlated with future consumption growth. Positive news about future raises the real value of nominal bonds and triggers negative comovement between bond returns and marginal utilities, resulting in a significant bond premium on announcement days. This effect is stronger for long-duration bonds and produces an upward sloping bond announcement premium, consistent with empirical evidence.

As shown in Ai and Bansal (forthcoming), in endowment economies where consumption cannot respond instantaneously to news, the existence of announcement premium implies that marginal utility must respond to changes in continuation utility and identifies generalized risk sensitivity in preferences. In production economies, the response of consumption and continuation utility may both affect the SDF and contribute to an announcement premium. However, we show that the endogenous response of consumption to announcements always results in a negative announcement premium and therefore, the significant announcement premium in the data must be due to the response of continuation utility to announcement through generalized risk sensitivity.

In production economies, contemporaneous consumption may respond positively or negatively to good news about future depending on whether the substitution effect or income effect dominates. If the substitution effect dominates, the agent value future consumption more and optimally choose to cut current consumption. Because equity is the claim to future consumption goods, when substitution effect dominates, equity value increases upon positive news about future. At the same time, the reduction of contemporaneous consumtion raises marginal utility. This negative comovement between marginal utility and equity valuation results in a negative announcement premium. Similarly, when income effect dominates, the negative comovement between consumption and equity market valuation also result in a negative announcement premium. In summary, even if one is willing to assume a high degree of risk aversion, the endogenous response of consumption to announcements cannot explain the macroeconomic announcement premium without generalized risk sensitivity.

Related literature   A growing body of literature documents the significance of the macroeconomic announcement premium. Savor and Wilson (2013) document that stock market returns and Sharpe ratios are significantly higher on days with macroeconomic news releases in the U.S., Brusa, Savor, and Wilson (2015) provides evidence that a similar phenomenon is true internationally. Lucca and Moench (2015) provide evidence for the FOMC announcement day premium a pre-FOMC announcement drift. Cieslak, Morse, and Vissing-Jorgensen (2015) provide evidence for significant stock market return over FOMC announcement cycles. Mueller, Tahbaz-Salehi, and Vedolin (2017) document an FOMC announcement premium on the foreign exchange market and attribute it to compensation to financially constrained intermediaries.

From the theoretical perspective, Ai and Bansal (forthcoming) take a revealed preference approach and establish the equivalence between the announcement premium and generalized risk sensitivity. Wachter and Zhu (2018) provide a recursive-preference based model where macroeconomic announcements reveal the probability of disasters. Different from the above literature, our production economy setup allows consumption to respond to announcements endogenously and affect the announcement premium. We show that generalized risk sensitivity identified in Ai and Bansal (forthcoming) continue to be the key mechanism to account for the announcement premium.

More generally, our paper builds on literature on asset pricing with non-expected utility. We refer the readers to Epstein and Schneider (2010) for a review of asset pricing studies with the maxmin expected utility model; Ju and Miao (2012) for an application of the smooth ambiguity-averse preference; Hansen and Sargent (2008) for the robust control preference; Routledge and Zin (2010) for an asset pricing model with disappointment aversion; and Bansal and Yaron (2004), Bansal (2007), and Hansen, Heaton, and Li (2008) for the long-run risks model that builds on recursive preferences. Skiadas (2009) provides an excellent textbook treatment of recursive-preferences in asset pricing theory.

The rest of the paper is organized as follows. We document some stylized facts for the equity premium for macroeconomic announcements in Section 2. In Section 3, we present a two period model to establish the equivalence between generalized risk sensitivity and the announcement premium. We present a continuous-time model to quantitatively account for the announcement premium in Section 4. In Section 5, we extend our result to production economies where consumption and investment are allowed to respond to announcements instantaneously. Section 6 concludes.

2 Stylized facts

To demonstrate the significance of the macroeconomic announcement premium, we focus on a relatively small set of pre-scheduled macroeconomic announcements that are released at monthly or less frequently. Within this category, we select the top five announcements ranked by investor attention by Bloomberg users. The five selected announcements constitute roughly thirty days per year for the period of 1961-2014. We summarize our main findings below and provide details about the data construction in Appendix A.

1. A large fraction of the market equity premium is realized on a relatively small number of trading days with pre-scheduled macroeconomic news announcements (See also Savor and Wilson (2013) and Lucca and Moench (2015)).

   Table I shows a substantial proportion of equity premium realized on announcement days. The cumulative stock market excess return on the thirty news announcement days averages 3.36% per year, accounting for about 55% of the annual equity premium (6.19%) during this period. This pattern is even more pronounced if we focus on more recent period of 1997-2014, where all announcements are available and there are fifty announcement days per year. In this period, the market equity premium is 7.44% per year, and the cumulative excess return of the S&P500 index on the fifty announcement days averages 8.24% per year. The equity premium on the rest of the trading days is not statistically different from zero.

2. The macroeconomic announcement is significant at high frequency.

   In Table III, we report the point estimates with standard errors for average hourly excess returns around announcements. We normalize the announcement time as hour zero. For $k = -5, -4, \cdots, 0, +1, +2$, the announcement window k in the table is defined as hour $k - 1$ to hour k. The hourly returns typically peak at the announcement, as reflected in row 1 of the table. The mean return during the announcement hour is economically important: 6.46 bps with a standard error of 2.71. The difference in mean excess returns in announcement hours compared to non-announcement hours, like in the daily returns data, is significant with a t-statistic of 2.06. In the case of FOMC announcements, consistent with Lucca and Moench (2015), the mean returns prior to the announcement window are statistically significant (see row 2 of Table III); this pre-announcement drift is not reflected in other macroeconomic announcements, as shown in row 3 of Table III.

3. The term structure of bond announcement premium is upward sloping.

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In Figure 1, we plot the average excess return of U.S. government bond with different maturities on announcement days. We normalize bond returns by the risk-free rate on announcement days, as measured by the announcement-day return of 30-day T bills. Consistent with the result reported in Savor and Wilson (2013), the announcement premium increases with maturity, with the 30-year Treasury bond requiring an announcement premium of roughly 4.3 bps on average on announcement days.

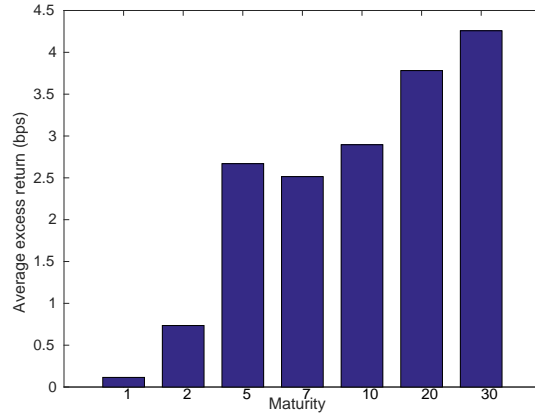Figure 1. **Announcement Premiums for Nominal Bonds**

Figure 1 plots the average announcement-day return for nominal government bond with different maturities. The horizontal axis is the bond maturity and the vertical axis is the average announcement-day excess return of bond with different maturities.

4. The significance of the macro announcement premium is robust both intraday and overnight.

   Some announcements are pre-scheduled during financial market trading hours (e.g., FOMC announcement) and others are pre-scheduled prior to the opening of financial markets (e.g., non-farm payrolls). We define intraday return (or open-to-close return) as the stock market return from the open to the close of a trading day and overnight return (or close-to-open return) as the return from the close of a trading day to the open of the next trading day. We compute intraday and overnight returns for periods with and without prescheduled announcements and report our findings in Table II. The average overnight return during the 1997-2014 period averages about 3.52 basis

points per day, and the average intraday return is close to zero[1]. Remarkably, both intraday and overnight return on pre-scheduled announcements days are large and small on non-announcements days. The average intraday return with announcement is 17.0 basis points, and the average overnight return with announcement is 9.32 basis points, while the average intraday and overnight return on non-announcement are not statistically different from zero. This new evidence reinforces the view that most of the equity premium realizes during periods of macroeconomic announcements.

5. The slope of the security market line, that is, the relationship between expected returns and β is positive and significant on announcement and is virtually flat on non-announcement days (see also Savor and Wilson (2014)).

In Figure 2, we plot the average return of the β-sorted portfolio on announcement days (circles) and that on non-announcement days (stars). There is a clear positive relationship between β and average returns on announcement days. On non-announcement days, however, the slope of the security market line is essentially flat.

Figure 2. **CAPM on Both Types of Days**
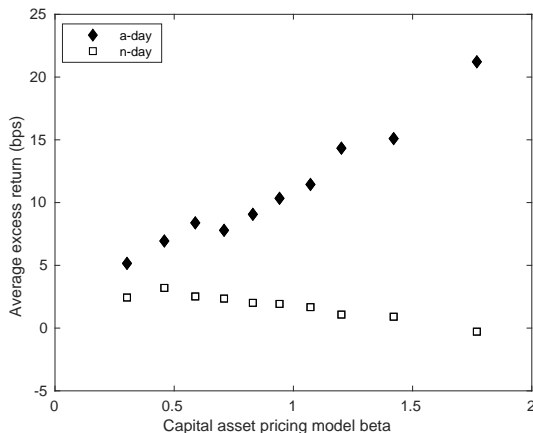
Figure 2 plots the security market line on announcement days (diamonds) and that on non-announcement days (squares). The horizonal axis is the average β for β-sorted portfolios, and the vertical axis is the daily average excess return measured in basis points.

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[1]The previous literature (for example, Kelly and Clark (2011) and Polk, Lou, and Skouras (2016)) documents that the overnight market return is on average higher than the intraday return in the United States. This is consistent with our average intraday and overnight empirical findings.

In the next sections, we present a theory of announcement premium to quantitatively explain the above stylized facts about the announcement premium.

3   A two-period model

In this section, we use a two-period setup to illustrate the concept of generalized risk sensitivity of preferences, which provides a necessary and sufficient condition for the existence of the announcement premium.

3.1   Asset market for announcements

We consider a representative-agent economy with two periods, 0 and 1. Period 0 has no uncertainty and the aggregate endowment is a known constant, $\bar{C}_0$. The aggregate endowment in period 1, denoted by $\bar{C}_1$, is a random variable. We assume a finite number of states: $s = 1, 2, \cdots N$ and denote the possible realizations of $\bar{C}_1$ as $\left\{\bar{C}_1(s)\right\}_{s=1,2,\cdots N}$. For simplicity, we assume that all states occur with equal probability: $\pi(s) = \frac{1}{N}$ for $s = 1, 2, \cdots, N$.

Agents in the economy start with an initial level of wealth W_0 and trade a vector of assets $j = 1, 2, \cdots, J$ on sequential markets. Asset j is a claim to a payoff $\{X_j(s)\}_{s=1}^{N}$ in period 1. In our economy, period 0 is further divided into two subperiods. In period 0^-, agents do not know any information about state s, and the price of asset j is denoted P_j^-. In period 0^+, an announcement arrives. For simplicity, we assume that the announcement fully reveals the true state s. The price of asset j at this point is denoted $P_j^+(s)$. Because the announcement resolves all uncertainty, all J assets must have the same risk-free return from period 0^+ to period 1, which we denote as $R_1(s)$.

An agent's utility maximization problem in period 0^+ can be written as

$$
\begin{aligned}
V^+\left(W^+(s)\right) &= \max\left\{u\left(C_0(s)\right) + \beta u\left(C_1(s)\right)\right\} \\
s.t. \quad &: \quad C_0(s) + \frac{1}{R_1(s)}C_1(s) = W^+(s),
\end{aligned}
$$

where $V^+(W^+(s))$ is the value function at 0^+ and $W^+(s)$ denotes the agent's wealth in period 0^+ after announcement s.

In period 0^-, before any information about the state s is revealed, the pre-announcement market opens and asset prices at this point are called pre-announcement prices and are

denoted by $\left\{P_j^-\right\}_{j=1,2,\cdots,J}$. The period 0^- budget constraint of the agent can be written as:

$$W^+(s) = W_0 - \sum_{j=1}^{J} \xi_j P_j^- + \sum_{j=1}^{J} \xi_j P_j^+(s). \tag{1}$$

The interpretation is that the agent starts with initial level of wealth W_0. She choose the holdings of J assets, denoted ξ_j. P_j^- is the pre-announcement price and P_j^+.

We assume that in period 0^-, the agent aggregates the uncertainty using a certainty equivalence functional $\mathcal{I}$. The utility maximization problem in period 0^- can be written as:

$$\max_{\{\xi_j\}_{j=1}^{J}} \mathcal{I}\left[V^+\left(W^+(s)\right)\right].$$

To close the model, we note that market clearing implies that $C_0(s) = \bar{C}_0$, and $C_1(s) = \bar{C}_1(s)$ for all s. It is worth noting that from individual investor's point of view, C_0 is chosen after the announcement is made, and therefore can depend on s. In equilibrium, however, the resource constraint requires that $C_0(s) = \bar{C}_0$ does not depend on s. In Figure 3, we illustrate the timing of information and consumption (top panel) and that of asset prices (bottom panel), assuming $N = 2$.

The announcement return of an asset, denoted by $R_A(s)$, is defined as the return of a strategy that buys the asset before the pre-scheduled announcement and sells immediately afterwards (assuming no dividend payment at 0^+):

$$R_A(s) = \frac{P^+(s)}{P^-}. \tag{2}$$

Our choice of numeraire in period 0^- should be interpreted as one unit of state-non-contingent consumption deliverd in period 0^+ (see equation (1)). Due to this choice of consumption numeraire, the risk-free announcement return must be one by no arbitrage. We say that an asset requires a positive announcement premium if $E[R_A(s)] > 1$.

We focus on announcement payoffs that are co-monotone with $\bar{C}_1(s)$. Asset j is said to have an announcement payoff comotone with respect to $\bar{C}_1(s)$ if $\forall s$ and s', $\bar{C}_1(s) \geq \bar{C}_1(s')$ if and only if $P_j^+(s) \geq P_j^+(s')$. We also impose some regularity conditions on the pair $\{u, \mathcal{I}\}$, which characterizes the agent's preference. We assume that both u and $\mathcal{I}$ are continuously differentiable. In addition, we assume that $\mathcal{I}$ is invariant to distribution, that is, $\mathcal{I}[X] = \mathcal{I}[X']$ if X' is a permutation of X.[2] We say that $\{u, \mathcal{I}\}$ represents expected utility

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[2]This is due to the assumption of equal probability for each state.

Figure 3. **Consumption and Asset Prices in the Two-period Model**
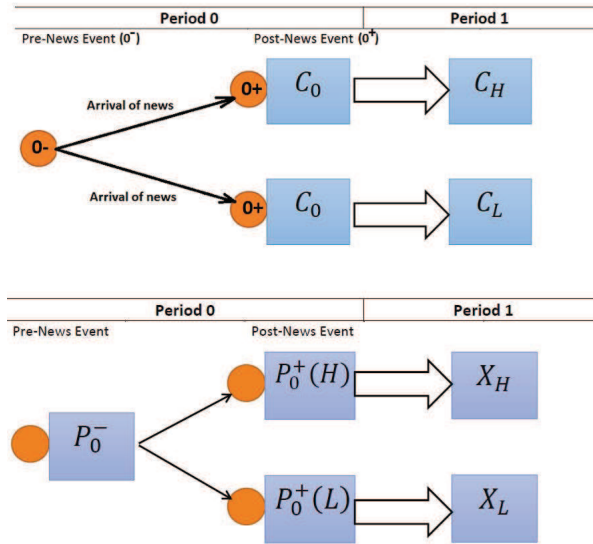
if $\mathcal{I}$ is the expectation operator, i.e. $\mathcal{I}[X] = E[X]$. We also define the concept of generalized risk sensitivity as in Ai and Bansal (2018).

Definition 1. *Generalized risk sensivity*

The certainty equivalent functional $\mathcal{I}$ is said to satisfy generalized risk sensitivity if

$$\mathcal{I}[X] \geq \mathcal{I}[X'] \tag{3}$$

whenever X second stochastic dominates X'. It is said to satisfy strict generalized risk sensitivity if the strict inequality in (3) holds whenever X strictly second stochastic dominates X'.

The following theorem provides a necessary and sufficient condition for the announcement return to be positive.

Theorem 1. *(Announcement Premium)*

1. *Expected utility is equivalent to the announcement premium being zero for all announcement payoffs.*

2. *Generalized risk sensitivity is equivalent to the announcement premium being non-negative for all announcement payoffs that are co-monotone with $\bar{C}_1$.*

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3. Strictly generalized risk sensivity is equivalent to the announcement premium being positive for all announcement payoffs that are strictly co-monotone with $\bar{C}_1$.

The above theorem simplifies and extends Theorem 2 in Ai and Bansal (2018). The assumption of finite state space greatly simplies our ananlysis. In addition, it allows us to prove 3), which is not available in Ai and Bansal (2018). Having provided a general characterization for announcement premium, we now turn to some concrete examples of risk preferences.

3.2   Simple examples

Expected utility   We first consider the case in which the representative agent has expected utility:[3] $E\left[u\left(C_0\left(s\right)\right)+\beta u\left(C_1\left(s\right)\right)\right]$, where u is strictly increasing and continuously differentiable.[4] The period 0^- price of one unit of period 1 consumption goods, which is measured in units of period 0^+ state-non-contingent consumption goods, can be computed from the ratio of marginal utilities: $\pi\left(s\right)\frac{\beta u'\left(C_1\left(s\right)\right)}{u'\left(C_0\right)}$.[5] Therefore, the pre-announcement price of an asset with payoff $\left\{X\left(s\right)\right\}_{s=1}^{N}$ is given by:

$$P^- = E\left[\frac{\beta u'\left(C_1\left(s\right)\right)}{u'\left(C_0\right)}X\left(s\right)\right].\tag{4}$$

In period 0^+, because s fully reveals the true state, the agent's preference is represented by

$$u\left(C_0\left(s\right)\right)+\beta u\left(C_1\left(s\right)\right).\tag{5}$$

As a result, for any s, the post-announcement price of the asset is

$$P^+\left(s\right) = \frac{\beta u'\left(C_1\left(s\right)\right)}{u'\left(C_0\right)}X\left(s\right).\tag{6}$$

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[3]We use the term "expected utility" to mean utility functions that are additively separable with respect to both time and states.

[4]Because the decision for C_0 is made at 0^+ after the announcement is made, from the agent's point of view, $C_0\left(s\right)$ is allowed to depend on s.

[5]From the agent's perspective, the marginal utility of one unit of period 0^+ state non-contingent consumption is $E\left[u'\left(C_0\left(s\right)\right)\right]$. In equilibrium, the market clearing condition implies that $C_0\left(s\right)$ cannot depend on s. Therefore, the expectation sign is not necessary: $E\left[u'\left(C_0\left(s\right)\right)\right] = u'\left(C_0\right)$. In the rest of this section, we will use the notation $C_0\left(s\right)$ when describing preference to emphasize that individual agent's consumption choice is allowed to depend on s. In the expressions of stochastic discount factors, we will impose market clearing and write C_0.

Clearly, the expected announcement return is $E\left[R_A\left(s\right)\right] = \frac{E\left[P^+(s)\right]}{P^-} = 1$. There can be no announcement premium on any asset under expected utility.

Recursive utility   We discuss an example of recursive utility of Kreps and Porteus (1978) and Epstein and Zin (1989) with constant elasticity of substitution (CES). Because all uncertainties are fully resolved after the announcement, in period 0^+, the agent first aggregates utility across time to compute continuation utility given announcement s:

$$\frac{1}{1-\frac{1}{\psi}}C_0^{1-\frac{1}{\psi}}\left(s\right) + \beta\frac{1}{1-\frac{1}{\psi}}C_1^{1-\frac{1}{\psi}}\left(s\right),$$

where ψ is the intertemporal elasticity of substitution parameter. Before the announcement, in period 0^-, the agent computes the certainty equivalent of the continuation utility:

$$\left\{E\left[\left\{C_0^{1-\frac{1}{\psi}}\left(s\right) + \beta C_1^{1-\frac{1}{\psi}}\left(s\right)\right\}^{\frac{1-\gamma}{1-1/\psi}}\right]\right\}^{\frac{1}{1-\gamma}}. \tag{7}$$

Again, the period 0^- Arrow-Debreu price of one unit of period 1 consumption goods can be computed from the ratio of marginal utilities: $m^*\left(s\right)\beta\left[\frac{C_1(s)}{C_0}\right]^{-\frac{1}{\psi}}$, where

$$m^*\left(s\right) = \frac{\left\{C_0^{1-\frac{1}{\psi}} + \beta C_1^{1-\frac{1}{\psi}}\left(s\right)\right\}^{\frac{1/\psi-\gamma}{1-1/\psi}}}{E\left[\left\{C_0^{1-\frac{1}{\psi}} + \beta C_1^{1-\frac{1}{\psi}}\left(s\right)\right\}^{\frac{1/\psi-\gamma}{1-1/\psi}}\right]}. \tag{8}$$

can be interpreted as A-SDF as in the case of the robust control preference. Clearly, m^* is a decreasing function of continuation utility if and only if $\gamma > \frac{1}{\psi}$, which coincides with the condition for preference for early resolution of uncertainty for this class of preferences.[6]

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[6]Note that the announcement leads uncertainty about C_1 to resolve before its realization, which corresponds to the case of early resolution of uncertainty in Kreps and Porteus (1978).

4 A Quantitative model of announcement premiums

4.1 Physical setup of the model

In this section, we present a continuous-time representative agent model to quantitatively account for the announcement premium. We assume that the consumption of the representative agent, C_t, follows

$$\frac{dC_t}{C_t} = x_t dt + \sigma dB_{C,t}, \tag{9}$$

where x_t is a continuous-time AR(1) process (an Ornstein-Uhlenbeck process) unobservable to the agent in the economy. The law of motion of x_t is

$$dx_t = a_x \left(\bar{x} - x_t \right) dt + \sigma_x dB_{x,t}. \tag{10}$$

The standard Brownian motions B_t and $B_{x,t}$ in equations (9) and (10), respectively, are independent.

At time 0, the agent's prior belief about x_0 can be represented by a normal distribution with mean m_0 and variance ζ_0. Although x_t is not directly obeservable, the agent can use two sources of information to update beliefs about x_t. First, the realized consumption path contains information about x_t, and second, at pre-scheduled discrete time points $T, 2T, 3T, \cdots$, additional signals about x_t are revealed through announcements. For $n = 1, 2, 3, \cdots$, we denote s_n as the signal observed at time nT and assume $s_n = x_{nT} + \varepsilon_n$, where ε_n is i.i.d. over time, and normally distributed with mean zero and variance σ_S^2.

Given the information structure, the posterior distribution of x_t is Gaussian and can be summarized by its first two moments. We define $\hat{x}_t = E_t[x_t]$ as the posterior mean and $\zeta_t = E_t\left[(x_t - \hat{x}_t)^2\right]$ as the posterior variance, respectively, of x_t given information up to time t. For $n = 1, 2, \cdots$, at time $t = nT$, the agent updates his beliefs using Bayes' rule:

$$\hat{x}_{nT}^+ = \frac{1}{q_{nT}^+} \left[\frac{1}{\sigma_S^2} s_n + \frac{1}{\zeta_{nT}^-} \hat{x}_{nT}^- \right]; \quad \frac{1}{\zeta_{nT}^+} = \frac{1}{\sigma_S^2} + \frac{1}{\zeta_{nT}^-}, \tag{11}$$

where $\hat{x}_{nT}^+$ and ζ_{nT}^+ are the posterior mean and variance after announcements, and $\hat{x}_{nT}^-$ and ζ_{nT}^- are the posterior mean and variance before announcements, respectively. A special case is that the annoucements can compeletly reveal the information about x_t, which means, $\sigma_S^2 = 0$.

In the interior of $(nT, (n+1)T)$, the agent updates his beliefs based on the observed

consumption process using the Kalman-Bucy filter:

$$d\hat{x}_t = a_x \left[\bar{x} - \hat{x}_t\right] dt + \frac{\zeta(t)}{\sigma} d\tilde{B}_{C,t}, \tag{12}$$

where the innovation process, $\tilde{B}_{C,t}$ is defined by $d\tilde{B}_{C,t} = \frac{1}{\sigma}\left[\frac{dC_t}{C_t} - \hat{x}_t dt\right]$. The posterior variance, $\zeta(t)$ satisfies the Riccati equation:

$$d\zeta(t) = \left[\sigma_x^2 - 2a_x\zeta(t) - \frac{1}{\sigma^2}\zeta^2(t)\right] dt. \tag{13}$$

We assume that the stock market is the claim to the following dividend process:

$$\frac{dD_t}{D_t} = \left[\bar{x} + \phi(x_t - \bar{x})\right] dt + \phi\sigma d\tilde{B}_{C,t} + \nu dB_{D,t}, \tag{14}$$

where we allow the leverage parameter $\phi > 1$ so that dividends are more risky than consumption, as in Bansal and Yaron (2004). In addition, the shock $dB_{D,t}$ is independent of $dB_{C,t}$ and $dB_{x,t}$.

4.2   Preferences and the SDF

We assume that the representative agent is endowed with a Kreps-Porteus preference with risk aversion γ and intertemporal elasticity of substitution ψ. In continuous time, the preference is represented by a stochastic differential utility, which can be specified by a pair of aggregators $(f, \mathcal{A})$ such that in the interior of $(nT, (n+1)T)$,

$$dV_t = \left[-f(C_t, V_t) - \frac{1}{2}\mathcal{A}(V_t)||\sigma_V(t)||^2\right] dt + \sigma_V(t) dB_t \tag{15}$$

We adopt the convenient normalization $\mathcal{A}(v) = 0$ (Duffie and Epstein (1992)), and denote $\bar{f}$ the normalized aggregator. Under this normalization, $\bar{f}(C, V)$ is:

$$\bar{f}(C, V) = \frac{\beta}{1 - 1/\psi} \frac{C^{1-1/\psi} - ((1-\gamma)V)^{\frac{1-1/\psi}{1-\gamma}}}{((1-\gamma)V)^{\frac{1-1/\psi}{1-\gamma}-1}}. \tag{16}$$

The case of $\psi = 1$ is obtained as the limit of (16) with $\psi \to 1$:

$$\bar{f}(C, V) = \beta V \left[(1-\gamma)\ln C - \ln\left[(1-\gamma)V\right]\right].$$

Because announcements typically result in discrete jumps in the posterior belief about x_t, the value function is typically not continuous at announcements. Given our normalization of the utility function, for $t = nT$, the pre-announcement utility and post-announcement utility are related by:

$$V_t^- = E_t^- \left[V_t^+ \right],$$

where E_t^- represents expectation with respect to the pre-announcement information at time t. In what follows, we assume $\gamma > \frac{1}{\psi}$ so that the above preference satisfies generalized risk sensitivty in Ai and Bansal (2018).

In the above setup, we can show that the value function of the representative agent takes the form

$$V \left(\hat{x}, t, C_t \right) = \frac{1}{1-\gamma} H \left(\hat{x}, t \right) C_t^{1-\gamma},$$

for some twice continuously differentiable function $H \left(\hat{x}, t \right)$. The HJB equation and the corresponding boundary conditions for $H \left(\hat{x}, t \right)$ can be found in Appendix section 3. Given the utility of the representative agent, the state price density, denoted $\{\pi_t\}_{t=0}^{\infty}$ can be characterized by the following theorem.

Theorem 2. *(State price density)*

For $n = 1, 2, 3 \cdots$, in the interior of $((n-1)T, nT)$, π_t is a continuous diffusion process with the law of motion

$$\frac{d\pi_t}{\pi_t} = -r \left(\hat{x}, t \right) dt - \sigma_\pi \left(\hat{x}, t \right) d\tilde{B}_t,$$

where $r \left(\hat{x}, t \right)$ is the instantaneous risk-free interest rate and $\sigma_\pi \left(\hat{x}, t \right)$ is the market price of risk. At announcements, $t = nT$, π_t is discountinuous, and the A-SDF is given by

$$m_t^* = \frac{\pi_t^+}{\pi_t^-} = \frac{H \left(\hat{x}_t^+, t^+ \right)^{\frac{\frac{1}{\psi} - \gamma}{1-\gamma}}}{E_t^- \left[H \left(\hat{x}_t^+, t^+ \right) \right]^{\frac{\frac{1}{\psi} - \gamma}{1-\gamma}}}.$$

Give the state prices density, we can compute the present value of the dividend stream. Denote $p \left(\hat{x}, t \right)$ as the price-to-dividend ratio, we have:

$$p \left(\hat{x}_t, t \right) D_t = E_t \left[\int_t^{\infty} \frac{\pi_s}{\pi_t} D_s ds \right].$$

We provide the ODE and the corresponding boundary conditions that determines $p \left(\hat{x}, t \right)$ in Appendix C.

In general, let j be an index of an asset with payout rate D_t^j, where we assume that

$$\frac{dD_t^j}{D_t^j} = \mu_t^j dt + \sigma_t^j d\tilde{B}_{C,t} + \nu_t^j dB_t^j,$$

where dB_t^j is a Brownian motion independent of $B_{C,t}$ and $B_{x,t}$. Let p_t^i be the price-to-dividend ratio of asset j. The cumulative return of the asset, R_t^j is defined as

$$\frac{dR_t^j}{R_t^j} = \frac{d\left[p_t^j D_t^j\right]}{p_t^j D_t^j} + D_t^j dt.$$

In the interior of $((n-1)T, nT)$, R_t^j is a continuous diffusion process of the form

$$\frac{dR_t^j}{R_t^j} = \mu_{R,t}^j dt + \sigma_{R,t}^i d\tilde{B}_t + \nu_{R,t}^j dB_t^j.$$

At announcements $t = nT$,

$$\frac{R_{t+}^j}{R_{t-}^j} = \frac{p_{t+}^j}{p_{t-}^j}.$$

We use the convention that quantities without the j superscript refers to the market equity.

We calibrate our model to standard parameters in the long-run risk literature and evaluate quantitatively its implications on the announcement premium. The parameters are listed in Table IV. We assume that announcements occur monthly, so that $T = \frac{1}{12}$.

4.3 Announcement premiums of equity

Let $(t, t + \Delta)$ be an infinitesimally small interval in the interior of $(nT, (n+1)T)$. The equity premium of asset j over the interval satisfies

$$E_t\left[\frac{R_{t+\Delta}^j}{R_t^j}\right] - e^{r_t \Delta} = -e^{r_t \Delta} Cov_t\left[\frac{\pi_{t+\Delta}}{\pi_t}, \frac{R_{t+\Delta}^j}{R_t^j}\right]. \tag{17}$$

Because both π_t and R_t^j are diffusion processes, standard results imply

$$E_t\left[\frac{R_{t+\Delta}^j}{R_t^j}\right] - e^{r_t \Delta} \approx \sigma_\pi(t)\sigma_R^j(t)\Delta. \tag{18}$$

In particular, as $\Delta \to 0$, $E_t \left[\frac{R_{t+\Delta}^j}{R_t^j} \right] - e^{r_t \Delta} \to 0$. In fact, using a log-linear approximation, we show in Appendix 3, that the market equity premium over the interval $(t, t+\Delta)$ is [7]

$$\left[\gamma\sigma + \frac{\frac{1}{\psi} - \gamma}{1 - \gamma} \frac{\gamma - 1}{a_x + \kappa} \frac{\zeta_t}{\sigma} \right] \left[\phi\sigma + \frac{\phi - \frac{1}{\psi}}{a_x + e^{-\bar{\varrho}}} \frac{\zeta_t}{\sigma} \right] \Delta, \tag{19}$$

where κ and $\bar{\varrho}$ are the steady-state consumption-wealth ratio and log price-to-dividend ratio, respectively.

Let $t = nT$ be an announcement time.

$$\frac{\pi_{t+\Delta}}{\pi_t^-} = \frac{\pi_t^+}{\pi_t^-} \frac{\pi_{t+\Delta}}{\pi_t^+} = \frac{H\left(\hat{x}_t^+, t^+\right)^{\frac{\frac{1}{\psi} - \gamma}{1 - \gamma}}}{E_t^- \left[H\left(\hat{x}_t^+, t^+\right) \right]^{\frac{\frac{1}{\psi} - \gamma}{1 - \gamma}}} \frac{\pi_{t+\Delta}}{\pi_t^+}.$$

As $\Delta \to 0$, $\pi_{t+\Delta} \to \pi_t^+$, but the term $\frac{H\left(\hat{x}_t^+, t^+\right)^{\frac{\frac{1}{\psi} - \gamma}{1 - \gamma}}}{E_t^- \left[H\left(\hat{x}_t^+, t^+\right) \right]^{\frac{\frac{1}{\psi} - \gamma}{1 - \gamma}}}$ does not vanish. Therefore, equity premium in general does not vanish as $\Delta \to 0$. In fact,

$$\lim_{\Delta \to 0} E_t \left[\frac{R_{t+\Delta}^j}{R_t^j} \right] = \frac{E_t^- \left[H\left(\hat{x}_t^+, t^+\right) \right]^{\frac{\frac{1}{\psi} - \gamma}{1 - \gamma}} E_t^- \left[p_{t+}^j \right]}{E_t^- \left[H\left(\hat{x}_t^+, t^+\right)^{\frac{\frac{1}{\psi} - \gamma}{1 - \gamma}} p_{t+}^j \right]} > 1$$

as long as the price-to-dividend ratio comoves positively with the continuation utility. We show in Appendix A that the announcement premium on the market equity can be approximated by

$$\lim_{\Delta \to 0} E_t \left[\frac{R_{t+\Delta}}{R_t} \right] - 1 \approx \frac{1}{2} \frac{\frac{1}{\psi} - \gamma}{1 - \gamma} \left\{ \left(\frac{\gamma - 1}{a_x + \kappa} \right)^2 - \frac{\frac{1}{\psi} - \gamma}{1 - \gamma} \left(\frac{\gamma - 1}{a_x + \kappa} \right)^2 + 2 \frac{\gamma - 1}{a_x + \kappa} \frac{\phi - \frac{1}{\psi}}{a_x + e^{-\bar{\varrho}}} \right\} \left[\zeta_T^- - \zeta_T^+ \right]. \tag{20}$$

Intuitively, (20) implies that the magnitude of the announcement premium is proportional to the amount of uncertainty reduction, $\zeta_T^- - \zeta_T^+$. The more informative announcements are, the higher the equity premium will be realized upon announcements. This observation

---

[7]In general, the equity premium depends on the state variable $\hat{x}$. The log-linear approximation does not capture this dependence. We use the log-linear approximation to illustrate the intuition of the model. All figures and calibration results are obtained based on the global solution of the PDE obtained by the Markov chain approximation method.

implies that the heterogeneity in the magnitude of the premium for different macroeconomic announcements can be potentially explained by the differences in their informativeness.

Equations (19) and (20) illustrates the difference between the equity premium realized on announcement days and non-announcement days. On non-announcement days, the equity premium vanished as $\Delta \to 0$. However, announcements are associated with a discrete amount of realization of equity premium (20) that does not vanish even as $\Delta \to 0$. We report the mean and standard deviation of equity return on announcement day and non-announcement days in Table V.

Empirically, most of the FOMC announcement premium is realized in the several hours before the announcement, as documented by Lucca and Moench (2015). As shown in Ai and Bansal (2018), assuming that the investors in the economy receive informative signals before announcements, the mechanism of our model is also consistent with pre-FOMC announcement drift.

4.4   Bond announcement premiums

In this section, we show that our calibrated model is also able to account for the announcement premium for government bonds. To model the announcement premium for nominal bond, we follow the approach of Piazzesi and Schneider (2006) and specify the dynamics of an inflation process. We assume that the nominal price process follows

$$\frac{dP_t}{P_t} = -\phi_P \left[(x_t + \theta_t) \, dt + \sigma dB_t \right].$$

Here, $\phi_P > 0$ captures the fact the inflation is negatively correlated with the long-run growth of the economy. In addition, the expected inflation depends also on θ_t, where

$$d\theta_t = -a_\theta \theta_t dt + \sigma_\theta dB_{\theta,t}.$$

We assume that θ_t is not observable, but is revealed by FOMC announcements. The inclusion of θ_t allows our model to jointly match the Sharpe ratio of nominal bond returns and the persistence of inflation.

We choose $\phi_P = 0.20$, $a_\theta = 0.02$ and $\sigma_\theta = 0.01$ to jointly match the moments of inflation dynamics estimated in Bansal and Shaliastovich (2013): a standard deviation of 1.76, an autocorrelation of 0.56 and a covariance with consumption growth of -0.11.

In Table VI, we replicate and extend Savor and Wilson (2013)'s evidence on the

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announcement premium for nominal bond with different maturities. As we show in the table, our model is consistent with the empirical evidence on the upward sloping announcement premium with respect to bond maturity, and our model matches the magnitude of the announcement premium quite well.

4.5   CAMP on announcement days

Empirically, the CAPM model holds very well on macroeconomic announcement days, where the expected return-β relationship is basically flat on non-announcement days (Savor and Wilson (2014)). There is a simple explanation for this phenomenon in our model. As we have seen from expressions (19) and (20), the market price of risk is much higher on announcement day than on non-announcement days.

Below we provide an expression for the security market line on announcement days and that on non-announcement days in our model, respectively. The risk premium of any asset on non-announcement days is given by (18). Let $(t, t + \Delta)$ be a small interval in the interior of $((n-1)T, nT)$,

$$E_t \left[\frac{R_{t+\Delta}^j}{R_t^j} \right] - e^{r_t \Delta} \approx \sigma_\pi (t) \sigma_R^j (t) \Delta = \sigma_\pi (t) \sigma_{R,t} \frac{\sigma_{R,t} \sigma_R^j (t)}{\sigma_{R,t}^2} \Delta.$$

Note that $\sigma_\pi (t) \sigma_{R,t} \Delta \approx E_t \left[\frac{R_{t+\Delta}}{R_t} \right] - e^{r_t \Delta}$ is the market risk premium, and $\frac{\sigma_{R,t} \sigma_R^j (t)}{\sigma_{R,t}^2}$ is the (local) CAPM β of asset j. Therefore, locally, CAPM holds, and

$$E_t \left[\frac{R_{t+\Delta}^j}{R_t^j} \right] - e^{r_t \Delta} \approx \beta \left\{ E_t \left[\frac{R_{t+\Delta}}{R_t} \right] - e^{r_t \Delta} \right\}.$$

The slope of the security market line is the market equity premium on non-announcement days.

Similarly, at announcements,

$$
\begin{aligned}
E_t^- \left[\frac{R_{t+}^j}{R_{t-}^j}\right] - 1 &= \frac{\left(E_t^-\left[\frac{R_{t+}^j}{R_{t-}^j}\right] - 1\right)\left(E_t^-\left[\frac{R_{t+}}{R_{t-}^j}\right] - 1\right)}{\left(E_t^-\left[\frac{R_{t+}}{R_{t-}}\right] - 1\right)^2} \times \left(E_t^-\left[\frac{R_{t+}}{R_{t-}}\right] - 1\right) \\
&= \frac{Cov_t^-\left(\frac{R_{t+}^j}{R_{t-}^j}, \frac{R_t^+}{R_t^-}\right)}{Var_t^-\left(\frac{R_t^+}{R_t^-}, \frac{R_t^+}{R_t^-}\right)} \times \left(E_t^-\left[\frac{R_{t+}}{R_{t-}}\right] - 1\right) \\
&= \beta \left(E_t^-\left[\frac{R_{t+}}{R_{t-}}\right] - 1\right).
\end{aligned}
$$

where $E_t^-\left[\frac{R_{t+}}{R_{t-}}\right] - 1$ is the market announcement premium and $\frac{Cov_t^-\left(\frac{R_{t+}^j}{R_{t-}^j}, \frac{R_t^+}{R_t^-}\right)}{Var_t^-\left(\frac{R_t^+}{R_t^-}, \frac{R_t^+}{R_t^-}\right)}$ is the CAPM β for asset j on announcement days.

Clearly, as $\Delta \to 0$, the slope of the security market line vanishes on non-announcement days, and remains strictly positive on announcement days. In Figure 4, we replicate Savor and Wilson (2014)'s findings and plot the expected return-β relationship on announcement days (diamonds) and that on non-announcement days (squares). We also plot in the same figure the security market line implied in our model. Because our model matches the market equity premium on announcement and non-announcement days fairly well, the implied security market line is also consistent with the empirical evidence.

5 Announcement premium in production economies

In previous sections of the paper, we have considered endowment economies where consumption does not respond to announcements instantaenously. In general, if investors can trade off consumption and investment, then it is possible that consumption responds to news immediately and contributes to an announcement premium. However, as we show below, in standard RBC models, the immediate response of consumption to announcement is quantitatively small. Moreover, it always contributes to a *negative* announcement premium, regardless of whether income effect or substitution effect dominates. It is possible for the production economy to generate a significant announcement premium, but it is due to generalized risk sensitivity in preferences, and not the endogenous response of consumption with respect to announcements.

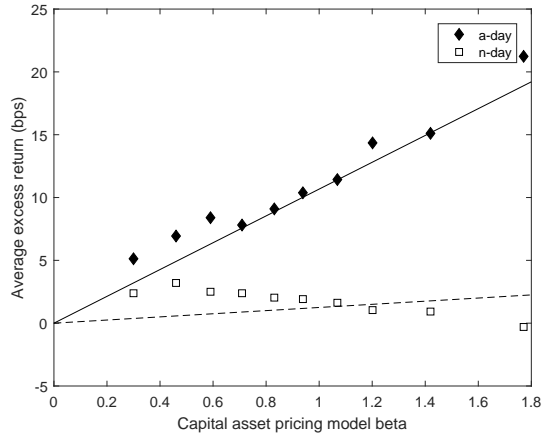Figure 4. **CAPM on Both Types of Days: Model Implications**

Figure 4 plots the security market line on announcement days (diamonds) and that on non-announcement days (squares). The horizonal axis is the average β for β-sorted portfolios, and the vertical axis is the daily average excess return measured in basis points. It also shows the estimated regression lines for returns against beta on announcement days (solid line) and non-announcement days (dashed line) in our model.

5.1 The production technology

We consider a production economy where total output is produced from capital and labor with a Cobb-Douglas production technology

$$Y = K^{\alpha} (AN)^{1-\alpha}.$$

For simplicity, we assume inelastic labor supply and set $N = 1$. The labor-augmenting productivity A_t follows the following law of motion:

$$\frac{dA_t}{A_t} = x_t dt + \sigma dB_t. \tag{21}$$

We assume that x_t is a continuous-time AR(1) process that follows the same law of motion as that in equation (10). Our setup is an RBC model with persistent productivity growth, essentially a continuous-time version of the Croce (2007) model.

We assume the same information structure as in the last section. That is, the representative agent in the economy can use two sources of information to update beliefs about x_t. First, the realized productivity contains information about x_t, and second, at pre-

scheduled discrete time points $T, 2T, 3T, \cdots$, additional signals about x_t are revealed through announcements. We assume that announcements perfectly reveal x_t and use $(\hat{x}_t, \zeta_t)$ to denote the posterior mean and variance of x_t. In this environment, the social planner's problem can be written as:

$$V(A_0, K_0, \hat{x}_0, \zeta_0) = \max_{\{C_t, I_t\}} E\left[\int_0^\infty \bar{f}(C_s, V_s)\, dt\right]$$

$$\text{s.t. } C_t + H(I_t, K_t) = A_t^{1-\alpha} K_t^\alpha$$

$$dK_t = (I_t - \delta K_t)\, dt$$

$$d\hat{x}_t = \kappa(\bar{x} - \hat{x}_t)\, dt + \frac{\zeta(t)}{\sigma_A} d\tilde{B}_t$$

$$d\zeta(t) = \left[\sigma_\theta^2 - 2a_x \zeta(t) - \frac{1}{\sigma_A^2}\zeta^2(t)\right] dt$$

$$dA_t = A_t\left[\hat{x}_t dt + \sigma_A d\tilde{B}_t\right]. \tag{22}$$

Here $H(I, K)$ is a quadratic adjustment cost function: $H(I, K) = I + \frac{1}{2}h_0\left(\frac{I}{K} - i^*\right)^2 K$.

It is straight forward to show that the value function and the policy function above satisfy a homogeneity property:

$$V(A, K, \hat{x}, \zeta) = \frac{1}{1-\gamma} v\left(\frac{K}{A}, \hat{x}, \zeta\right)^{1-\gamma} A^{1-\gamma} \tag{23}$$

$$C(A, K, \hat{x}, \zeta) = c\left(\frac{K}{A}, \hat{x}, \zeta\right) A, \quad I(A, K, \hat{x}, \zeta) = i\left(\frac{K}{A}, \hat{x}, \zeta\right) A, \tag{24}$$

for some normalized value function v and policy functions c and i. In what follows, we will write the normalized capital stock as $k = \frac{K}{A}$, and the normalized value and policy functions as $v(k, \hat{x}, \zeta)$, $c(k, \hat{x}, \zeta)$, and $i(k, \hat{x}, \zeta)$. Also, define

$$q(k, \hat{x}, \zeta) = 1 + h_0\left[i(k, \hat{x}, \zeta) - i^*\right] \tag{25}$$

be the Tobin's Q implied by the optimal investment policy. Let t be an announcement time. Note that upon announcements, $\hat{x}$ jumps from $\hat{x}_t^-$ to x_t, and ζ jumps from ζ_t^- to zero, as announcements full reveal the true state. Because both K_t and A_t are continuous processes, k_t remains continuous at announcements.

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5.2 Announcement premiums

We keep the preference parameters the same as before and choose standard technology parameters from the literature of production economies with long-run risks. The implied macroeconomic moments as well as asset pricing statistics are list in Table VII.

Our benchmark calibration generates an announcement premium of 8.4 bps on announcement days with a financial leverage of 3. Consumption is allowed to respond immediately to announcements in the production economy; therefore, the announcement premium comes both from the response of consumption with respect to announcements and the impact of announcement on continuation utility. The A-SDF in the production economy can be written as

$$
m_t^* = \frac{\pi_t^+}{\pi_t^-} = \left(\frac{c\left(k_t, x_t, 0\right)}{c\left(k_t, \hat{x}_t^-, \zeta_t^-\right)} \right)^{-\frac{1}{\psi}} \left(\frac{v\left(k_t, x_t, 0\right)}{\left\{ E_t^-\left[v\left(k_t, x_t, 0\right)^{1-\gamma} \right] \right\}^{\frac{1}{1-\gamma}}} \right)^{\frac{1}{\psi}-\gamma}.
$$

Therefore, the announcement premium for market equity is given by:

$$
-Cov_t\left(m_t^*, \frac{q\left(k_t, x_t, 0\right)}{q\left(k_t, \hat{x}_t^-, \zeta_t^-\right)} \right),
$$

where upon announcement, Tobin's Q jumps from $q\left(k_t, \hat{x}_t^-, \zeta_t^-\right)$ to $q\left(k_t, x_t, 0\right)$.

We show in the Appendix D that via a log-linear approximation, the announcement premium can be written as:

$$
\frac{1}{\psi}\left[\frac{\partial \ln c\left(k_t, x_t, 0\right)}{\partial \ln x_t} \right]\left[\frac{\partial \ln q\left(k_t, x_t, 0\right)}{\partial \ln x_t} \right]\zeta_t^- + \left(\gamma - \frac{1}{\psi} \right)\left[\frac{\partial \ln v\left(k_t, x_t, 0\right)}{\partial \ln x_t} \right]\left[\frac{\partial \ln q\left(k_t, x_t, 0\right)}{\partial \ln x_t} \right]\zeta_t^-.
$$
(26)

The first term reflects the impact of endogenous response of consumption on announcement premium, and the second term reflect the effect of generalized risk sensitivty on announcement premium.

In Figure 5, we plot the impulse response functions (IRF) for consumption (top panel), continuation utility (second panel), SDF (third panel), and Tobin's Q with respect to a one-standard deviation of innovations in announcements with respect to x_t, where the horizontal axis is the number of years after announcement, and the vertical axis is log deviations from steady state. We make several observations here. First, upon a positive news about future, consumption responds negatively and the first term in (26) is negative. An IES of $\psi = 2$ in our

calibration implies that the substitution effect dominates the income effect and consumption drops upon postive news about productivity in the future. Due to the resource constraint, a drop in consumption must be associated with an increase in investment as output does not respond instantaneously to news. Note that Tobin's Q is an increasing function of investment as shown in equation (25). As a result, consumption and Tobin's Q move in oppositive directions upon a positive news about future, and the endogenous response of consumption contribute negatively to the announcement premium.
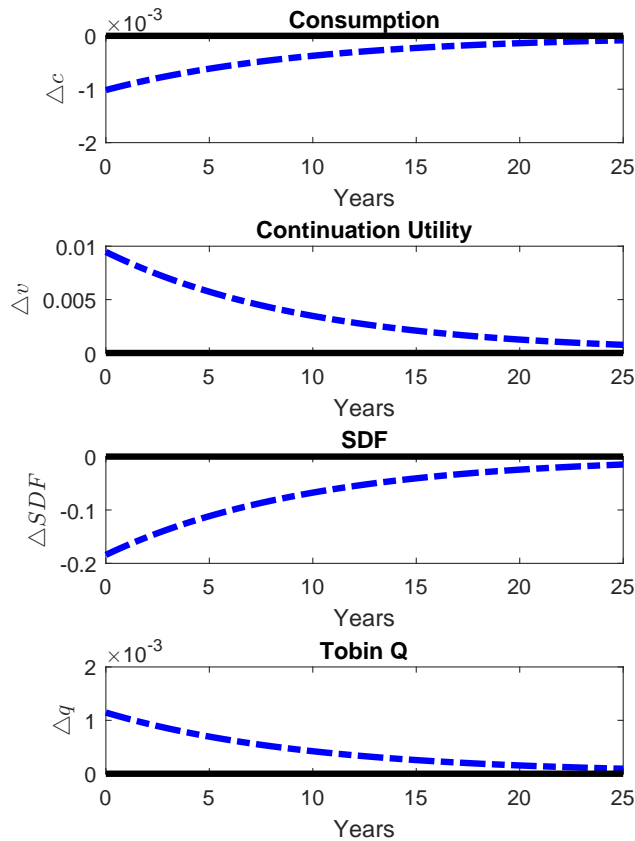
Figure 5. **Impulse Response Functions**

Figure 5 plots the impulse response functions of consumption, continuation utility, SDF and Tobin's Q with respect to one standard deviation in innovation of announcement in the production economy with $\gamma = 20$ and $\psi = 2$.

Second, both Tobin's Q and continuation utility respond positively to news, generating a

positive announcement premium. A positive news about future is always associated with an increase in continuation utility. Due to a stong generalized risk sensitivity, the innvoations in SDF is mostly dominated by the changes in continuation utlity, i.e. the second term in (26). As shown in Figure 5, continuation utility responds positvely to news and SDF responds negatively to news. In addition, the magnitude of the response of continuation utility and SDF with respect to the announcement is many times higher than that of consumption. Consequently, the second term in equation (26), the part of the announcement premium that comes from generalized risk sensitivity dominates and result in a significant equity premium on announcement days.

The fact that endogenous response of consumption contributes negatively to announcement premium does not depend on whether the income or the substitution effect dominates. It is merely the implication of the resource constraint and the optimality condition of investment (25). The resource constraint implies that consumption and investment must move in opposite directions, and the convexity of the adjustment cost function implies that Tobin's Q is a monotone function of investment. As a result, the immediate response of consumption and Tobin's Q with respect to announcements must be in opposite directions. Of course, over time, a positive news is often associated with increases in both consumption and investment in the future, but this channel does not affect the announcement premium unless the utility features generalized risk sensitivity.

To illustrate the negative announcement premium associated with immediate response of consumption with respect to announcements, in Figure 6 and 7, we plot the impulse response functions of consumption, continuation utility, SDF, and Tobin's Q with respect to announcements for an expected utility model with high IES: $\psi = \frac{1}{\gamma} = 2$, and those for an expected utility model with low IES, $\psi = \frac{1}{\gamma} = 0.2$, respectively. In the case with high IES, substitution effect dominates, consumption responds negatively, and investment responds positively to announcements. Under expected utility, SDF depends only on consumption, and as a result, the negative comovement of consumption and Tobin's Q produces a negative announcement premium.

Figure 6. **Impulse Response Functions**

Figure 6 plots the impulse response functions of consumption, continuation utility, SDF and Tobin's Q with respect to one standard deviation in innovation of announcement in the production economy with $\psi = \frac{1}{\gamma} = 2$.

In the case of low IES ($\psi = 0.2$), the income effect dominates, consumption rises after the announcement and investment and Tobin's Q drop. Again, the negative comovement between consumption and Tobin's produces a negative announcement premium. Note also, in both expected utility models, because consumption changes in the only reason for SDF to respond to announcements, the innovations of SDF is orders of magnitude smaller than that in the model with recursive utility. Consequently, the announcement premium that comes from the endogenous response of consumption is not only negative in sign, but also negligible in magnitude.
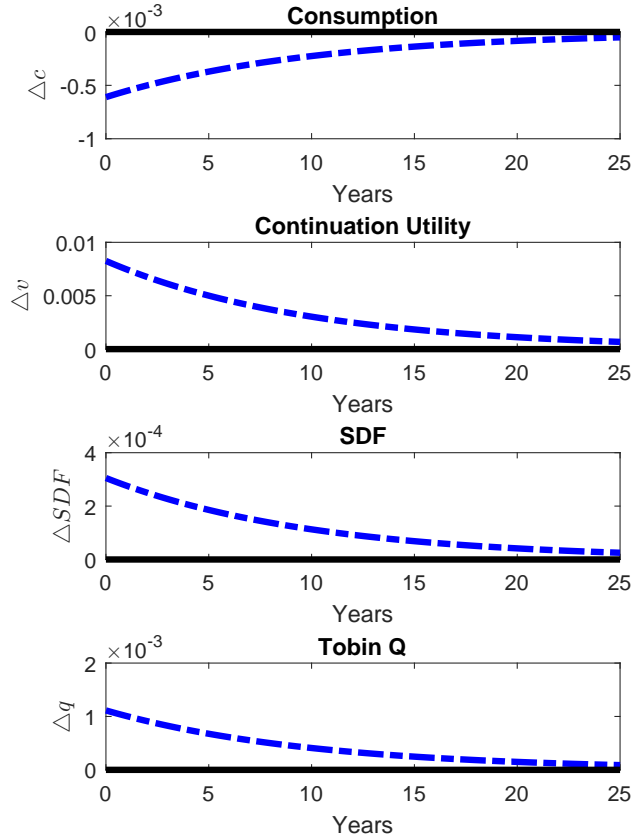
Figure 7. **Impulse Response Functions**
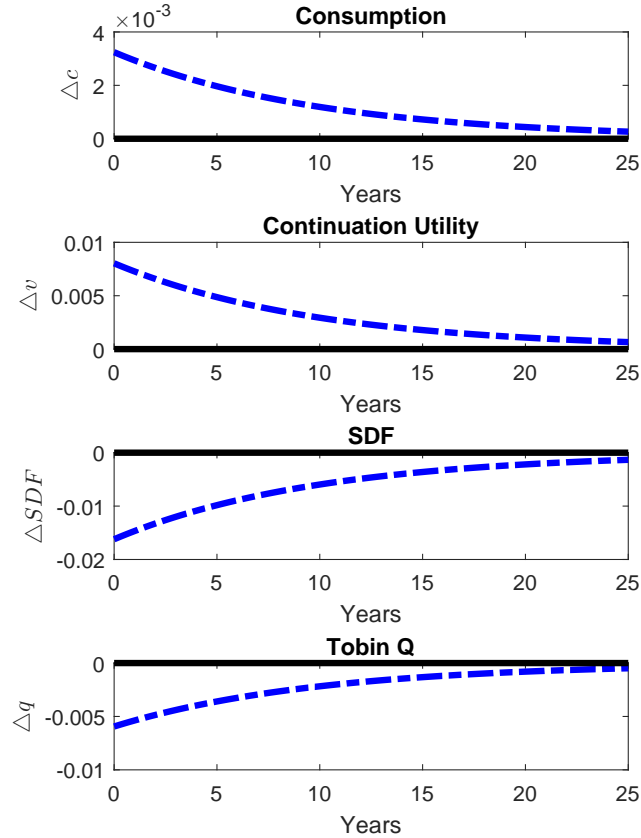
Figure 7 plots the impulse response functions of consumption, continuation utility, SDF and Tobin's Q with respect to one standard deviation in innovation of announcement in the production economy with $\psi = \frac{1}{\gamma} = 0.2$.

6   Conclusion

Motivated by the fact that a large fraction of the market equity premium is realized on a small number of trading days with significant macroeconomic announcements, in this paper, we provide a theory and a quantitative analysis of the equity premium for macroeconomic announcements. We show that generalized risk sensitivity in preferences provides a necessary

and sufficient condition for the existence of announcement premiums in endowment economies where consumption does not respond instantaneously to announcements. We present a quantitative model that matches several stylized facts on the announcement premium, including the announcement premiums for equity and bond, and that of the cross-section of $\beta-$sorted portfolios. We also show that the economic mechanism that we demonstrate in this paper is robust to extension to production economies, where consumption is allowed to respond instantaneous to announcements.

APPENDICS

The following appendices provide details of the data construction for the stylized facts in Section 2, the proofs of the main results in Section 3 and details of the quantative models in Section 4 and 5 of the paper. Appendix A is the data appendix. Appendix B contains the proofs of Theorem 1. Appendix C provides the proof of Theorem 2 and numeircal solutions of the endowment economy. Appendix D

Appendix A   Data Description

Macroeconomic announcements   We focus on the top five macroeconomic news ranked by investor attention among all macroeconomic announcements at the monthly or lower frequencies. They are unemployment/non-farm payroll (EMPL/NFP) and the producer price index (PPI) published by the U.S. Bureau of Labor Statistics (BLS), the FOMC statements, gross domestic product (GDP) reported by the U.S. Bureau of Economic Analysis, and the Institute for Supply Management's Manufacturing Report (ISM) released by Bloomberg.[8]

The EMPL/NFL and the PPI are both published monthly and their announcement dates come from the BLS website. The BLS began announcing its scheduled release dates in advance in 1961, which is also the starting date for our EMPL/NFL announcements sample. The PPI data series starts in 1971.[9] There are a total of eight FOMC meetings each calendar year, and the dates of FOMC meetings are taken from the Federal Reserve's web site. The FOMC statements began in 1994, when the Committee started announcing its decision to the markets by releasing a statement at the end of each meeting. For meetings lasting two calendar days, we consider the second day (the day the statement is released) as the event date. GDP is released quarterly beginning from 1997, which is the first year that full data are available, and the dates come from the BEA's website.[10]   Finally, ISM is a monthly

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[8]Both unemployment and non-farm payroll information are released as part of the Employment Situation Report published by the BLS. We treat them as one announcement.

[9]While the CPI data are also available from the BLS back to 1961, once the PPI starts being published it typically precedes the CPI announcement. Given the large overlap in information between the two macro releases, much of the news content in the CPI announcement is already known to the market at the time of its release. For this reason, we opt in favor of using the PPI.

[10]GDP growth announcements are made monthly according to the following pattern: in April the advance estimate for Q1 GDP growth is released, followed by a preliminary estimate of the same Q1 GDP growth in May and a final estimate given in the June announcement. Arguably, most uncertainty about Q1 growth is resolved once the advance estimate is published, and most learning by the markets will occur prior to this release. For this reason, we focus only on the four advance estimate release dates every year.

announcement with dates coming from Bloomberg starting from 1997. Our sample ends in 2014.

High-frequency returns In Table III, we report the average stock market excess returns over one-hour intervals before and after news announcements in event time. Here, we use high-frequency data for the S&P 500 SPDR that runs from 1997 to 2013 and comes from the TAQ database. For each second, the median price of all transactions occurring in that second is computed. Prices at lower frequency intervals (e.g. hourly prices) are then constructed as the price for the last (most recent) second in that interval when transactions were observed. The exact times at which the announcements are released are reported by Bloomberg.

Appendix B   Proof of Theorem 1

Here we provide a proof for Theorem 1 of the paper in a two-period model by assuming i) a finite state space, ii) fully revealing announcements, and iii) equal probability of each state. The proof in the paper shows that the conclusion of the theorem holds in a fully dynamic model without assuming fully revealing announcements. In addition, the assumption of a finite space with equal probability can be replaced by a continuum. Because the proof of Theorem 2 under the assumption of finite state space is relatively simple and does not require functional analysis in infinite dimensional spaces, we present such a proof in this note.

Under Assumptions i)-iii), the intertemporal preference can be written as $u(C_0) + \beta \mathcal{I}[u(C_1)]$, where the certainty equivalence functional $\mathcal{I}$ maps random variables into the real line. Because the probability space is finite, we can identify every random variable with a $N-$dimensional vector. We denote $V = [V_1, V_2, \cdots, V_N]$, where $V_s = u(C_{1,s})$ is the date-1 utility of the agent. We assume that the range of $u(C)$, denoted Ψ, is a closed interval on the real line. The set of all Ψ-valued random variables can be denoted as Ψ^N. As in the paper, we make the following assumptions on $\mathcal{I}$:

Assumption 1: $\mathcal{I}$ is continuously differentiable with strictly positive partial derivatives.

Assumption 2: $\mathcal{I}[k] = k$ whenever k is a constant.

As we show in equation (12) and (13) on page 9 of the paper,

$$P^- = E\left[m^*(s) P^+(s)\right], \tag{27}$$

where the A-SDF, $m^*(s)$ is given by:

$$m^*(s) = \frac{1}{\pi(s)} \frac{\frac{\partial}{\partial V_s}\mathcal{I}[V]}{\sum_{n=1}^{N} \frac{\partial}{\partial V_n}\mathcal{I}[V]}. \tag{28}$$

In the above equation, $\frac{\partial}{\partial V_s}\mathcal{I}[V]$ denotes the partial derivative of $\mathcal{I}[V]$ with respect to its sth element. Equation (27) implies that the announcement premium is positive (negative) if

$$E\left[m^*(s) P^+(s)\right] \leq (\geq) E\left[P^+(s)\right].$$

We first show that Condition 1 in the paper is equivalent to the "negative comonotonicity" of the partial derivatives of $\mathcal{I}[V]$:

Lemma 1. *The following two conditions are equivalent:*

1. *The announcement premium is non-negative for all payoffs that are comonotone with* V.[11]

2. *For any* $V \in \Psi^N$,

$$\left(\frac{\partial}{\partial V_s}\mathcal{I}[V] - \frac{\partial}{\partial V_{s'}}\mathcal{I}[V]\right)(V_s - V_{s'}) \leq 0. \tag{29}$$

Proof. First, we assume that 1) is true and prove 2) by contradiction. Suppose there exist V and s, s' such that $V_s > V_{s'}$ and $\frac{\partial}{\partial V_s}\mathcal{I}[V] > \frac{\partial}{\partial V_{s'}}\mathcal{I}[V]$. Consider the following payoff:

$$X(n) = V_n \quad for \quad n = s, s'; \quad X(n) = 0 \quad otherwise.$$

Clearly, X is comonotone with V, and therefore positively correlated with $m^*(s)$ defined in (28). Therefore,

$$P^- = E\left[m^*(s) X(s)\right] > E\left[m^*(s)\right] E\left[X(s)\right] = E\left[X(s)\right],$$

contradicting a non-negative announcement premium.

---

[11]Recall that a payoff X is comonotone with V if $\forall s$ and s' such that $X(s) \cdot X(s') \neq 0$, $[X(s) - X(s')][V(s) - V(s')] \geq 0$.

Next, we assume that 2) is true and prove 1). Take any X that is comonotone with V, then

$$P^- = E\left[m^*(s)X(s)\right] \le E\left[m^*(s)\right]E\left[X(s)\right] = E\left[X(s)\right]$$

because $m^*(s)$ and $X(s)$ are negatively correlated. $\square$

Lemma 1 establishes the equivalence between non-negative announcement premium (for payoffs that are comonotone with continuation utility) and inequality (29). Inequality (29) is known to be a characterization of Schur concave functions, which is equivalent to monotone with respect to second order stochastic dominance for functions defined on finite probability spaces with equal probabilities. We summarize the equivalence results in the following lemma and refer the readers to Marshal and Okin or Muller and Stoyan for reference of such results.

Lemma 2. *For any $\mathcal{I}$ that satisfies Assumption 1, the following two statements are equivalent:*

1. *$\mathcal{I}[V]$ is non-decreasing in second order stochastic dominance if and only if for any $V \in \Psi^N$, $\left(\frac{\partial}{\partial V_s}\mathcal{I}[V] - \frac{\partial}{\partial V_{s'}}\mathcal{I}[V]\right)(V_s - V_{s'}) \le 0$.*

2. *$\mathcal{I}[V]$ is strictly increasing in second order stochastic dominance if and only if any $V \in \Psi^N$, $\left(\frac{\partial}{\partial V_s}\mathcal{I}[V] - \frac{\partial}{\partial V_{s'}}\mathcal{I}[V]\right)(V_s - V_{s'}) \le 0$, and strict inequality holds whenever $V_s \ne V_{s'}$.*

3. *$\mathcal{I}[V]$ is non-increasing in second order stochastic dominance if and only if any $V \in \Psi^N$, $\left(\frac{\partial}{\partial V_s}\mathcal{I}[V] - \frac{\partial}{\partial V_{s'}}\mathcal{I}[V]\right)(V_s - V_{s'}) \ge 0$.*

With the above we are ready to prove Theorem 1 in the paper. The first part of Theorem 1 is

1. *The announcement premium is zero for all assets if and only if I is expected utility.*

   Proof. If $\mathcal{I}$ is the expectation operator, that is, $\mathcal{I}[V] = \sum_{s=1}^{N}\pi(s)V(s)$, then by (28), $m^*(s) = 1$, and the announcement premium must be zero for all assets. Conversely, if the announcement premium is zero for all assets, we must have $m^*(s) = m^*(s')$ for all s, s', otherwise we can construct an asset with nonzero payoff in state s and s' that requires a non-trivial announcement premium. This implies that $\left(\frac{\partial}{\partial V_s}\mathcal{I}[V] - \frac{\partial}{\partial V_{s'}}\mathcal{I}[V]\right)(V_s - V_{s'}) = 0$ for all s, s'. For any $V \in \Psi^N$, note that $E[V] \ge_{SSD} V$, by the above lemma, we must have

$$\mathcal{I}[V] = \mathcal{I}[E[V]] = E[V],$$

where the last equality uses Assumption 2. □

The second part of Theorem 1 is a direct consequence of Lemma 1 and Lemma 2:

2. *The announcement premium is non-negative for all assets with payoffs comonotone with V if and only I is non-decreasing with respect to second order stochastic dominance.*

From the above discussion, it is clear that a stronger version of the above result is also true, that is,

3. *The announcement premium is strictly positive for all assets with payoffs strongly comonotone with V if and only I is strictly increasing with respect to second order stochastic dominance.*

Appendix C Details of the Continuous-time model

In this section, we provide details of the solution of the continuous-time model. We provide the solution to the model with periodic announcement in Section 4.2 and 4.3 of the main text of the paper.

Value function of the representative agent Because announcements fully reveal the value of x_t at nT, $\zeta_{nT}^+ = 0$. We start from $\zeta_0 = 0$. In the interior of $(0, T)$, the standard optimal filtering implies that the posterior mean and variance of x_t are given by equations (12) and (13). Here ζ_t has a closed form solution:

$$\zeta(t) = \frac{\sigma_x^2 \left(1 - e^{-2\hat{a}t}\right)}{(\hat{a} - a_x) e^{-2\hat{a}t} + a_x + \hat{a}}, \tag{30}$$

where $\hat{a} = \sqrt{a_x^2 + (\sigma_x/\sigma)^2}$. In general, we can write $\zeta_t = \zeta(t \bmod T)$ for all t.[12]

Using the results from Duffie and Epstein (1992), the representative consumer's preference is specified by a pair of aggregators $(f, \mathcal{A})$ such that the utility of the representative agent, V_t is the solution to the following stochastic differential equation:

$$dV_t = [-f(C_t, V_t) - \frac{1}{2}\mathcal{A}(V_t)||\sigma_V(t)||^2]dt + \sigma_V(t)dB_t,$$

---

[12]We use the notation $t \bmod T$ for the remainder of t divided by T.

for some square-integrable process $\sigma_V(t)$. We adopt the convenient normalization $\mathcal{A}(V) = 0$ (Duffie and Epstein (1992)), and denote $\bar{f}$ the normalized aggregator, and $\bar{V}_t$ the corresponding utility process. Under this normalization,

$$\bar{f}(C,V) = \frac{\beta}{1 - 1/\psi} \frac{C^{1-1/\psi} - ((1-\gamma)V)^{\frac{1-1/\psi}{1-\gamma}}}{((1-\gamma)V)^{\frac{1-1/\psi}{1-\gamma}-1}} \cdots$$

Due to homogeneity, the value function is of the form

$$\bar{V}(\hat{x}_t, t, C_t) = \frac{1}{1-\gamma} H(\hat{x}_t, t) C_t^{1-\gamma}, \tag{31}$$

where $H(\hat{x}, t)$ satisfies the following Hamilton–Jacobi–Bellman (HJB) equation:

$$\frac{\beta}{1 - \frac{1}{\psi}} H(\hat{x}_t, t)^{1 - \frac{1-\frac{1}{\psi}}{1-\gamma}} + \left(\hat{x}_t - \frac{1}{2}\gamma\sigma^2 - \frac{\beta}{1 - \frac{1}{\psi}} \right) H(\hat{x}_t, t) + \frac{1}{1-\gamma} H_t(\hat{x}_t, t)$$

$$+ \left[\frac{1}{1-\gamma} a_x(\bar{x} - \hat{x}_t) + \zeta_t \right] H_x(\hat{x}_t, t) + \frac{1}{2} \frac{1}{1-\gamma} H_{xx}(\hat{x}_t, t) \frac{\zeta_t^2}{\sigma^2} = 0, \tag{32}$$

with the boundary condition that for all $n = 1, 2 \cdots$

$$H\left(\hat{x}_{nT}^-, nT\right) = E\left[H\left(\hat{x}_{nT}^+, nT\right) \big| \hat{x}_{nT}^-, \zeta_{nT}^- \right]. \tag{33}$$

We solve $H(\hat{x}, t)$ by applying the finite difference method to the HJB equation (32), subject to the boundary condition (49).

Asset prices For $n = 1, 2, \cdots$, in the interior of $(nT, (n+1)T)$, the law of motion of the state price density, π_t satisfies the stochastic differential equation of the form:

$$d\pi_t = \pi_t \left[-r(\hat{x}, t) \, dt - \sigma_\pi(\hat{x}, t) \, d\tilde{B}_{C,t} \right],$$

where

$$r(\hat{x}, t) = \beta + \frac{1}{\psi}\hat{x} - \frac{1}{2}\gamma \left(1 + \frac{1}{\psi} \right) \sigma^2 - \frac{\gamma - \frac{1}{\psi}}{1 - \gamma} \frac{H_x(\hat{x}_t, t)}{H(\hat{x}_t, t)} \zeta(t) + \frac{1}{2} \frac{\frac{1}{\psi} - \gamma}{1 - \gamma} \frac{1 - \frac{1}{\psi}}{1 - \gamma} \left(\frac{H_x(\hat{x}_t, t)}{H(\hat{x}_t, t)} \right)^2 \left(\frac{\zeta(t)}{\sigma} \right)^2$$

is the risk-free interest rate, and

$$\sigma_\pi(\hat{x}, t) = \gamma\sigma - \frac{\frac{1}{\psi} - \gamma}{1 - \gamma} \frac{H_x(\hat{x}_t, t)}{H(\hat{x}_t, t)} \frac{\zeta(t)}{\sigma}$$

is the market price of the Brownian motion risk.

We denote $p(\hat{x}_t, t)$ as the price-to-dividend ratio. For $t \in (nT, (n+1)T)$, the price of the claim to the dividend process can then be calculated as:

$$p(\hat{x}_t, t) D_t = E_t \left[\int_t^{(n+1)T} \frac{\pi_s}{\pi_t} D_s ds + \frac{\pi_{(n+1)T}}{\pi_t} p\left(\hat{x}_{(n+1)T}^-, (n+1)T^-\right) D_{(n+1)T} \right].$$

The above present value relationship implies that

$$\pi_t D_t + \lim_{\Delta \to 0} \frac{1}{\Delta} \{ E_t \left[\pi_{t+\Delta} p(\hat{x}_{t+\Delta}, t+\Delta) D_{t+\Delta} \right] - \pi_t p(\hat{x}_t, t) D_t \} = 0. \qquad (34)$$

Equation (34) can be used to show that the price-to-dividend ratio function must satisfy the following PDE:

$$1 - p(\hat{x}, t) \varpi(\hat{x}, t) + p_t(\hat{x}, t) - p_x(\hat{x}, t) \nu(\hat{x}, t) + \frac{1}{2} p_{xx}(\hat{x}, t) \frac{\zeta^2(t)}{\sigma^2} = 0, \qquad (35)$$

where the functions $\varpi(\hat{x}, t)$ and $\nu(\hat{x}, t)$ are defined by:

$$
\begin{aligned}
\varpi(\hat{x}, t) &= r(\hat{x}, t) - \mu - \phi(\hat{x} - \bar{x}) + \phi \sigma \sigma_\pi(\hat{x}, t) \\
\nu(\hat{x}, t) &= a_x(\hat{x} - \bar{x}) + \frac{\zeta(t) \sigma_\pi(\hat{x}, t)}{\sigma} - \phi \sigma_\pi(\hat{x}, t)
\end{aligned}
$$

Also, equation (34) can be used to derive the following boundary condition for $p(\hat{x}, t)$:

$$p\left(\hat{x}_T^-, T^-\right) = E \left[\frac{H\left(\hat{x}_T^+, T^+\right)^{\frac{\frac{1}{\psi} - \gamma}{1 - \gamma}}}{E\left[H\left(\hat{x}_T^+, T^+\right) \middle| \hat{x}_T^-, \zeta_T^- \right]^{\frac{\frac{1}{\psi} - \gamma}{1 - \gamma}}} p\left(\hat{x}_T^+, T^+\right) \middle| \hat{x}_T^-, \zeta_T^- \right]. \qquad (36)$$

Again, we focus on the steady-state and denote $p(\hat{x}, 0) = p(\hat{x}, nT^+)$, and $p(\hat{x}, T) = p(\hat{x}, nT^-)$. Under this condition PDE (35) together with the boundary condition can be used to determined the price-to-dividend ratio function.

We define $\mu_{R,t}$ to the instantaneous risk premium, that is,

$$\mu_{R,t} dt = \frac{1}{p(\hat{x}_t, t) D_t} \{ D_t dt + E_t \, d\left[p(\hat{x}_t, t) D_t \right] \}. \qquad (37)$$

In the interior of $(nT, (n+1)T)$, the instantaneous risk premium, $\mu_{R,t} - r(\hat{x}, t)$ can be

computed as

$$\left[\mu_{R,t} - r\left(\hat{x}, t\right)\right] dt = -Cov_t \left[\frac{d\left[p\left(\hat{x}_t, t\right) D_t\right]}{p\left(\hat{x}_t, t\right) D_t}, \frac{d\pi_t}{\pi_t}\right].$$

We have:

$$\mu_{R,t} - r\left(\hat{x}, t\right) = \left[\gamma\sigma - \frac{\frac{1}{\psi} - \gamma}{1 - \gamma} \frac{H_x\left(\hat{x}_t, t\right)}{H\left(\hat{x}_t, t\right)} \frac{\zeta\left(t\right)}{\sigma}\right] \left[\phi\sigma + \frac{p_x\left(\hat{x}, t\right)}{p\left(\hat{x}, t\right)} \frac{\zeta\left(t\right)}{\sigma}\right]. \tag{38}$$

Log-linear Approximation   To gain a better understanding on how the risk premium and the announcement premium depend on the parameters, we approximate the function $H\left(\hat{x}, t\right)$ and $p\left(\hat{x}, t\right)$.

Note that the term $\beta H\left(\hat{x}_t, t\right)^{-\frac{1-\frac{1}{\psi}}{1-\gamma}}$ is the consumption-wealth ratio. Consider the following log-linear expansion: $e^{\ln x} \approx e^{\ln \bar{x}} + e^{\ln \bar{x}} \left(\ln x - \ln \bar{x}\right)$,

$$\beta H\left(\hat{x}_t, t\right)^{-\frac{1-\frac{1}{\psi}}{1-\gamma}} \approx \kappa + \kappa \left[\ln \beta - \frac{1 - \frac{1}{\psi}}{1 - \gamma} \ln H\left(\hat{x}_t, t\right) - \ln \kappa\right]$$

where $\kappa = \beta H\left(\bar{x}, t\right)^{-\frac{1-\frac{1}{\psi}}{1-\gamma}}$ is the consumption-wealth ratio at steady state.

Therefore, we can approximate $\beta H\left(\hat{x}_t, t\right)^{-\frac{1-\frac{1}{\psi}}{1-\gamma}}$ as

$$\frac{\beta}{1 - \frac{1}{\psi}} \left[H\left(\hat{x}_t, t\right)^{1-\frac{1-\frac{1}{\psi}}{1-\gamma}} - 1\right] \approx \frac{1}{1 - \frac{1}{\psi}} \left[\kappa + \kappa \left[\ln \beta - \frac{1 - \frac{1}{\psi}}{1 - \gamma} \ln H\left(\hat{x}_t, t\right) - \ln \kappa\right] - \beta\right]$$

$$= -\frac{\kappa}{1 - \gamma} \ln H\left(\hat{x}_t, t\right) + \xi_0$$

where we denote $\xi_0 \triangleq \frac{1}{1 - \frac{1}{\psi}} \left[\kappa - \beta - \kappa\left(\ln \kappa - \ln \beta\right)\right]$.

The HJB equation (32) is written as

$$\xi_0 - \frac{\kappa}{1 - \gamma} \ln H\left(\hat{x}_t, t\right) + \left(\hat{x}_t - \frac{1}{2}\gamma\sigma^2\right) + \frac{1}{1 - \gamma} \frac{H_t\left(\hat{x}_t, t\right)}{H\left(\hat{x}_t, t\right)}$$

$$+ \left[\frac{1}{1 - \gamma} a_x\left(\bar{x} - \hat{x}_t\right) + \zeta_t\right] \frac{H_x\left(\hat{x}_t, t\right)}{H\left(\hat{x}_t, t\right)} + \frac{1}{2}\frac{1}{1 - \gamma} \frac{H_{xx}\left(\hat{x}_t, t\right)}{H\left(\hat{x}_t, t\right)} \frac{\zeta_t^2}{\sigma^2} = 0, \tag{39}$$

The solution to the partial differential equation (PDE) (39) is given by:

$$H(\hat{x}, t) = e^{\frac{1-\gamma}{a_x + \kappa} \hat{x} + h(t)},$$

where $h(t)$ satisfy the following ODE:

$$-\kappa h(t) + h'(t) + f(t) = 0, \tag{40}$$

where $f(t)$ is defined as:

$$f(t) = \frac{(1-\gamma)^2}{a_x + \kappa} \zeta(t) + \frac{1}{2} \frac{(1-\gamma)^2}{(a_x + \kappa)^2} \frac{1}{\sigma^2} \zeta^2(t) - \frac{1}{2} \gamma (1-\gamma) \sigma^2 + a_x \bar{x} \frac{1-\gamma}{a_x + \kappa} + \xi_0.$$

The general solution to (40) is of the following form on $(0, T)$:

$$h(t) = h(0) e^{\kappa t} - e^{\kappa t} \int_0^t e^{-\kappa s} f(s) \, ds.$$

We focus on the steady state in which $h(t) = h(t \bmod T)$ and use the convention $h(0) = h(0^+)$ and $h(T) = h(T^-)$.

To log-linear approximate $p(\hat{x}, t)$, let $\varrho(\hat{x}, t) = \ln p(\hat{x}, t)$, then equation (35) can be written as:

$$e^{-\varrho(\hat{x}, t)} - \varpi(\hat{x}, t) + \varrho_t(\hat{x}, t) - \varrho_x(\hat{x}, t) \nu(\hat{x}, t) + \frac{1}{2} \left[\varrho_{xx}(\hat{x}, t) + \varrho_x^2(\hat{x}, t) \right] \frac{\zeta^2(t)}{\sigma^2} = 0. \tag{41}$$

Note that $\hat{x}_t$ is itself an Ornstein-Uhlenbeck process with steady state $\bar{x}$. Using a log-linear approximation around $\hat{x} = \bar{x}$, we can replace the term $e^{-\varrho(\hat{x}, t)}$ with $e^{-\varrho(\hat{x}, t)} \approx e^{-\bar{\varrho}} - e^{-\bar{\varrho}} [\varrho(\hat{x}, t) - \bar{\varrho}]$, where we denote $\bar{\varrho} \equiv \varrho(\bar{x}, t)$, and write

$$e^{-\bar{\varrho}} [1 + \bar{\varrho} - \varrho(\hat{x}, t)] - \varpi(\hat{x}, t) + \varrho_t(\hat{x}, t) - \varrho_x(\hat{x}, t) \nu(\hat{x}, t) + \frac{1}{2} \left[\varrho_{xx}(\hat{x}, t) + \varrho_x^2(\hat{x}, t) \right] \frac{\zeta^2(t)}{\sigma^2} = 0. \tag{42}$$

We conjecture that $\varrho(\hat{x}, t) = A\hat{x} + B(t)$, and equation (42) can be used to solve for A and $B(t)$ by the method of undetermined coefficients to get $A = \frac{\phi - \frac{1}{\psi}}{a_x + e^{-\bar{\varrho}}}$.

Using the log-linearization result to evaluate equation (38) at $\hat{x} = \bar{x}$, we obtain (19). In addition, using $p(\hat{x}_T^+, T^+) \approx e^{A\hat{x}_T^+ + B(T^+)}$, we can compute the expectation in (36) explicitly and obtain (20).

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Numerical Solutions To solve the PDE (35) with the boundary condition (36), we consider the following auxiliary problem:

$$p\left(x_t, t\right) = E\left[\int_t^T e^{-\int_t^s \varpi(x_u, u)du} ds + e^{-\int_t^T \varpi(x_u, u)du} p\left(x_T, T\right)\right], \tag{43}$$

where the state variable x_t follows the law of motion;

$$dx_t = -\nu\left(\hat{x}, t\right) dt + \frac{\zeta\left(t\right)}{\sigma} dB_t. \tag{44}$$

Note that the solution to (43) and (36) satisfies the same PDE. Given an initial guess of the pre-announcement price-to-dividend ratio, $p^-\left(x_\tau, \tau\right)$, we can solve (43) by the Markov chain approximation method (Kushner and Dupuis (2001)):

1. We first start with an initial guess of a pre-announcement price-to-dividend ratio function, $p\left(x_T, T\right)$.

2. We construct a locally consistent Markov chain approximation of the diffusion process (44) as follows. We choose a small dx, let $Q = \left|\nu\left(\hat{x}, t\right)\right| dx + \left(\frac{\zeta(t)}{\sigma}\right)^2$, and define the time increment $\Delta = \frac{dx^2}{Q}$ be a function of dx. Define the following Markov chain on the space of x:

$$\begin{aligned}
\Pr\left(x + dx \,|x\right) &= \frac{1}{Q}\left[-\nu\left(\hat{x}, t\right)^+ dx + \frac{1}{2}\left(\frac{\zeta\left(t\right)}{\sigma}\right)^2\right], \\
\Pr\left(x - dx \,|x\right) &= \frac{1}{Q}\left[-\nu\left(\hat{x}, t\right)^- dx + \frac{1}{2}\left(\frac{\zeta\left(t\right)}{\sigma}\right)^2\right].
\end{aligned}$$

One can verify that as $dx \to 0$, the above Markov chain converges to the diffusion process (44) (In the language of Kushner and Dupuis (2001), this is a Markov chain that is locally consistent with the diffusion process (44)).

3. With the initial guess of $p\left(x_T, T\right)$, for $t = T - \Delta, T - 2\Delta$, etc, we use the Markov chain approximation to compute the discounted problem in (43) recursively:

$$p\left(x_t, t\right) = \Delta + e^{-\varpi(x, t)\Delta} E\left[p\left(x_{t+\Delta}, t + \Delta\right)\right],$$

until we obtain $p\left(x, 0\right)$.

4. Compute an updated pre-announcement price-to-dividend ratio function, $p\left(x_T, T\right)$

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using (36):

$$p\left(\hat{x}_T^-, T^-\right) = E\left[\left.\frac{H\left(\hat{x}_T^+, T^+\right)^{\frac{1}{\psi}-\gamma}}{E\left[H\left(\hat{x}_T^+, T^+\right)\middle|\hat{x}_T^-, \zeta_T^-\right]^{\frac{1}{\psi}-\gamma}}p\left(\hat{x}_T^+, T^+\right)\middle|\hat{x}_T^-, \zeta_T^-\right].$$

Go back to step 1 and iterate until the function $p\left(x_T, T\right)$ converges.

Appendix D   Details of the Production Economy

Using the normalizations (24) and define

$$V\left(A, K, \hat{x}, \zeta\right) = H\left(\frac{K}{A}, \hat{x}, \zeta\right) A^{1-\gamma} \tag{45}$$

, we can derive the following HJB equation:

$$
\begin{aligned}
0 = \max_{c,i} \quad & \frac{\beta}{1-\frac{1}{\psi}}c(k, \hat{x}, t)^{1-\frac{1}{\psi}}\left[(1-\gamma) H(k, \hat{x}, t)\right]^{1-\frac{1-\frac{1}{\psi}}{1-\gamma}} \\
& + H(k, \hat{x}, t)\left[(1-\gamma)\hat{x} + \frac{1}{2}\sigma_A^2\gamma(\gamma-1) - \frac{\beta(1-\gamma)}{1-\frac{1}{\psi}}\right] \\
& + H_t(k, \hat{x}, t) + H_k(k, \hat{x}, t)\left[(i-\delta k) - k\hat{x} + \gamma\sigma_A^2 k\right] \\
& + H_x(k, \hat{x}, t)\left(\kappa\left(\bar{\theta} - \hat{x}_t\right) + (1-\gamma)\zeta(t)\right) \\
& - k\zeta(t) H_{kx}(k, \hat{x}, t) + \frac{1}{2}\sigma_A^2 k^2 H_{kk}(k, \hat{x}, t) + \frac{1}{2}\frac{\zeta^2(t)}{\sigma_A^2}H_{xx}(k, \hat{x}, t)
\end{aligned}
\tag{46}
$$

Since goods market clearing satisfies

$$c + i + \frac{h_0}{2}\left(\frac{i}{k} - i^*\right)^2 k = k^\alpha \tag{47}$$

, the optimal investment policy function from (46) is equivalent to solve

$$0 = \max_i \quad \frac{\beta}{1-\frac{1}{\psi}}\left[k^\alpha - i - \frac{h_0}{2}\left(\frac{i}{k} - i^*\right)^2 k\right]^{1-\frac{1}{\psi}}\left[(1-\gamma) H(k, \hat{x}, t)\right]^{1-\frac{1-\frac{1}{\psi}}{1-\gamma}} + H_k(k, \hat{x}, t)\cdot i$$

The FOC of i equals

$$\beta \left[(1-\gamma) H(k,\hat{x},t)\right]^{1-\frac{1-\frac{1}{\psi}}{1-\gamma}} \left[k^\alpha - i - \frac{h_0}{2}\left(\frac{i}{k} - i^*\right)^2 k\right]^{-\frac{1}{\psi}} \left(1 + h_0\left(\frac{i}{k} - i^*\right)\right) = H_k(k,\hat{x},t) \tag{48}$$

We solve $H(k,\hat{x},t)$ by applying the finite difference method to the HJB equation (46), subject to the boundary condition, for all $n = 1, 2 \cdots$

$$H\left(k_{nT}, \hat{x}_{nT}^-, nT\right) = E\left[H\left(k_{nT}, \hat{x}_{nT}^+, nT\right)\big| \hat{x}_{nT}^-, \zeta_{nT}^-\right]. \tag{49}$$

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Table I

Market Return on Announcement and Non-announcement Days

	# days p. a.	daily prem.	daily std.	premium p.a.
Market	252	2.46 *bps*	98.2 *bps*	6.19%
Announcement	30	11.21 *bps*	113.8 *bps*	3.36%
No Announcement	222	1.27 *bps*	95.9 *bps*	2.82%

This table documents the mean and the standard deviation of the market excess return during the 1961-2014 period. The column "# days p.a." is the average number of trading days per annum. The second column shows daily market equity premium on all trading days, announcement days, and non-announcement days respectively. The column "daily std." is the standard deviation of daily returns. The column "premium p.a." is the cumulative market excess returns within a year, which is computed by multiplying the daily premium by the number of event days and converting it into percentage points.

Table II

Intraday and Overnight Return with and without Announcement

Intrady Returns			
	# of Events	Mean (StErr)	Std
All Intraday	4278	-0.55 bps (1.67)	109
Announcement	336	17.0 bps (6.43)	118
FOMC	136	23.2 bps (10.0)	117
ISM	204	12.1 bps (8.26)	118
No Announcement	3942	-2.05 bps (1.72)	108

Overnight Returns			
	# of Events	Mean (StErr)	Std
All Overnight	4277	3.52 bps (1.06)	69.4
Announcement	544	9.32 bps (3.38)	78.8
NFP	204	16.2 bps (5.47)	78.1
PPI	204	-2.17 bps (5.86)	83.7
GDP	136	16.2 bps (6.02)	70.2
No Announcement	3733	2.67 bps (1.11)	67.9

This table decomposes intraday and overnight returns into announcement day returns and non-announcement day returns. The first column is the total number of events during the sample period of 1997-2014. The mean return on event days is measured in basis points with standard error of the point estimate in parenthesis.

Table III

Average Hourly Return around Announcements

Announcement window	−5	−4	−3	−2	−1	0	+1	+2
All Announcements	0.78	3.25	2.00	−0.17	−1.51	6.16	−2.32	2.11
	(0.26)	(2.34)	(1.85)	(0.02)	(−1.64)	(1.64)	(−1.24)	(0.90)
FOMC	13.35	13.54	7.65	3.37	4.78	0.19	5.84	−5.1
	(2.43)	(2.45)	(3.08)	(1.43)	(2.92)	(0.20)	(0.82)	(−1.08)
All w/o FOMC	−0.37	0.42	0.94	−0.69	−2.96	6.88	−3.22	2.72
	(−0.16)	(0.72)	(0.37)	(−0.30)	(−2.53)	(1.26)	(−1.43)	(2.56)

This table reports the average hourly excess return around announcements during the 1997-2013 period, with standard errors of the point estimates in parenthesis. The announcement time is normalized as hour zero. For $k = -5, \ -4, \cdots, \ 0, \ +1, \ +2$, announcement window k stands for the interval between hour $k-1$ and hour k. The row "All announcements" is the average hourly return on all announcement days; "FOMC" is the average hourly return on FOMC announcement days, and "All w/o FOMC" is the average hourly return on all announcement days except FOMC announcement days.

Table IV

Calibrated Parameter Values

The benchmark model: endowment economy

β	γ	ψ	$\bar{x}$	a_x	σ_x	σ	ν	ϕ	σ_s	$\frac{1}{T}$
0.02	20	2	1.5%	0.02	0.11%	3%	4%	3	0	12

Inflation parameters

ϕ_P		a_θ		σ_θ
0.20		0.02		0.01

The production economy

	α	δ	$\bar{x}$	a_x	σ_θ	σ_A	h_0	
	1/3	10%	2%	0.10	0.26%	6%	5	

This table presents the calibrated parameters of our models. The three panels report the parameters used for the benchmark model (endowment economy), inflation and the production economy, respectively.

Table V

Table V

Market Return on Announcement and Non-announcement Days: Model implications

	Data		Model	
	daily prem.	daily std.	daily prem.	daily std.
Market	2.46 bps	98.2 bps	1.56 bps	71.71 bps
Announcement	11.21 bps	113.8 bps	10.67 bps	121.68 bps
No Announcement	1.27 bps	95.9 bps	1.25 bps	69.99 bps

This first two columns documents the mean and the standard deviation of the market excess return during the 1961-2014 period. The first column is the daily market equity premium on all days, that on announcement days, and that on days with no announcement. The column "daily std." is the standard deviation of daily returns. The last two columns show our model's corresponding model moments of equity premium in the benchmark model.

Table VI

Announcement-Day Treasury Bond Excess Returns: Data and Model Implications

	1y	2y	5y	7y	10y	20y	30y
Data (bps)	0.11	0.73	2.67	2.51	2.90	3.78	4.26
Model (bps)	0.27	0.52	1.20	1.61	2.15	3.45	4.24

This table presents average excess return of U.S. government bond with different maturities on announcement days. We normalize bond returns by the risk-free rate on announcement days, as measured by the announcement-day return of 30- day T bills. The second row shows our model impliations

Table VII

Moments in the Production Economy

Moments		Model
$E\left[\frac{C_{t+1}}{C_t}\right]$	Average consumption growth	1.8%
$Std\left[\frac{C_{t+1}}{C_t}\right]$	Std of consumption growth	3.18%
$Std\left[\frac{I_{t+1}}{I_t}\right]$	Std of investment growth	5.94%
$Std\left[\frac{Y_{t+1}}{Y_t}\right]$	Std of output growth	4.02%
$E\left[R_f\right]$	Average risk-free rate	1.85%
$Std\left[R_f\right]$	Std of risk-free rate	0.96%
$E\left[R - R_f\right]$	Market equity premium (per year)	4.77%
$E\left[R_A - R_f\right]$	Announcement premium (per day)	8.4bps
$E\left[R_N - R_f\right]$	Non Announcement premium (per day)	1.1bps

This table reports the moments in the production economy with recursive utility.