Identifying preference for early resolution from asset prices

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This paper develops a revealed preference theory for preference for the timing of resolution of uncertainty based on asset pricing data and present corresponding empirical evidence. Our main theorem provides a characterization of the representative agent's preference for early resolution of uncertainty in terms of the risk premium of assets realized during the period of resolution of informativeness of macroeconomic announcements. Empirically, we show how data on the dynamics of the S&P 500 index options prices around FOMC announcements can be used to identify investors' preference for the timing of resolution of uncertainty.

1 Introduction

In this paper, we develop a revealed preference theory that allows us to use asset market based evidence to detect investors' preference for the timing of resolution of uncertainty. Our main theorem states that the representative agent prefers early (late) resolution of uncertainty if and only if claims to market volatility, which can be constructed from index options, require a *positive* (negative) premium during the period where the informativeness of macroeconomic announcements is resolved. Empirically, using evidence on the implied volatility of S&P 500 index options around FOMC announcements, we find supportive evidence for investors' preference for *early* resolution of uncertainty.

The notion of preference for the timing of resolution of uncertainty is formally developed in Kreps and Porteus [29]. Models with preference for early resolution (PER) of uncertainty, in particular, the recursive preference with constant elasticity, has been widely applied in the asset pricing literature, for example, Epstein and Zin [13, 15], Weil [41], Bansal and Yaron [4], and Hansen, Heaton, and Li [19], among others. However, in the constant elasticity recursive utility model, and in most applied asset pricing models, PER is typically intertwined with other aspects of preferences, such as risk aversion and intertemporal elasticity of substitution. As a result, the exactly role for PER in asset pricing is not well understood. In addition, the asset pricing implications of models with PER are typically similar to a broad class of preferences that satisfy generalized risk sensitivity (Ai and Bansal [2]). The purpose of this paper is to provide an equivalent characterization of PER in terms of asset prices and use asset market data to identify investors' preference for the timing of resolution of uncertainty.

Preferences are often the starting point of macroeconomic analysis and asset pricing studies. Modern economic theory implies that asset prices are evaluated using marginal utilities and therefore the empirical evidence from asset markets can potentially provide valuable guidance for the choice of preferences in macroeconomic analysis in general, and in policy studies in particular. However, results that allow researchers to use relevant asset market based evidence to identify exact properties of preferences are rare. In this paper, we provide a general result that allow researchers to build such links and apply our result to establish a necessary and sufficient condition for PER in terms of asset prices. We show that the representative investor prefers early resolution of uncertainty if and only if claims to market volatility requires a positive premium during the period of *resolution of informativeness*, that is, a period in which the uncertainty about the informativeness of macroeconomic announcements is resolved. We provide empirical evidence for investors' preference for timing of resolution of uncertainty based on our theoretical insights and found

evidence supportive of PER.

Our main theorem builds on the notion of generalized risk sensitivity (GRS) developed in Ai and Bansal [2]. Ai and Bansal [2] define GRS to be the class of all preferences where marginal utility of consumption decreases with respect to continuation utility. The Theorem of Generalized Risk Sensitivity in Ai and Bansal [2] demonstrates that a non-negative announcement premium for all assets that are comonotone with continuation utility is equivalent to GRS. However, GRS is a very general condition that includes many examples of non-expected utility as special cases, for example, the Gilboa and Schmeidler [16] maxmin expected utility which is indifferent between the timing of resolution of uncertainty, and the Kreps and Porteus [29] utility that prefers early resolution of uncertainty. The announcement premium itself does not allow us to identify PER.

The condition of GRS, however, implies that ranking of marginal utility of consumption is the inverse ranking of the level of continuation utility and allows us to design a thought experiment to identify PER from risk premiums. PER implies that the utility level of the representative agent is higher when she expects a more informative macroeconomic announcement and lower when she expects a non-informative announcement. The key insight of our paper is that under GRS, PER is equivalent to a negative co-monotonicity between marginal utility and the expected informativeness of the upcoming macroeconomic announcement. Because more informative macroeconomic announcements are associated with higher realized stock market volatility upon announcements, the risk premium on claims to market volatility can be used to detect the ranking of marginal utility with respect to the informativeness of macroeconomic announcements, and therefore, PER. The asset pricing test implied by our theorem is easily implementable as claims to market volatility can be replicated using a portfolio of options.

Based on the above insight, we design an empirical exercise to identify PER from the asset market data. Our empirical exercise contains two steps. The first step is to identify a period of resolution of the informativeness of macroeconomic announcements. Empirically, we use the predictability of the informativeness of FOMC announcements by the term structure of implied volatility ahead of announcements to identify the period of resolution of informativeness of FOMC announcements. The second step is to estimate the risk premium for claims to market vocality associated with FOMC announcements to identify PER. Based on standard results from option pricing, for example, Carr and Madan [7], Britten-Jones and Neuberger [5], and Jiang and Tian [24], we construct a replicating portfolio for market volatility and found evidence of a positive premium, which is consistent with preference for early resolution of uncertainty.

Related literature   Our theoretical work builds on the literature that studies decision making under non-expected utility. We adopt the general representation of dynamic preferences of Strzalecki [40]. The generality of our approach is important given that our purpose is to identify the property of preferences from asset market data and given that PER if often intertwined with other aspects of preferences in the popular recursive utility formulation used in applied asset pricing work.[1] In particular, the general setup allows us to distinguish different decision theoretic concepts such as generalized risk sensitivity, uncertainty aversion, and preference for early resolution of uncertainty.

Our framework includes most of the non-expected utility models in the literature as special cases, such as the maxmin expected utility of Gilboa and Schmeidler [16], the dynamic version of which is studied by Chen and Epstein [8] and Epstein and Schneider [11]; the recursive preference of Kreps and Porteus [29] and Epstein and Zin [13]; the robust control preference of Hansen and Sargent [22, 23] and the related multiplier preference of Strzalecki [39]; the variational ambiguity-averse preference of Maccheroni, Marinacci, and Rustichini [32, 33]; the smooth ambiguity model of Klibanoff, Marinacci, and Mukerji [27, 28]; and the disappointment aversion preference of Gul [18].

Earlier work on the reveal preference approach for expected utility includes Green and Srivastava [17] and Epstein [14]. More recently, Kubler, Selden, and Wei [30] and Echenique and Saito [9] developed asset market based characterizations of the expected utility model. None of the above papers focus on GRS and aim to connect their result to asset market data as we do.

Our paper is also related to several papers that study PER in asset pricing models. Ai [1] demonstrate that in a production economy with long-run risk, most of the welfare gain from knowing more information about future is due to PER, not due to the fact that agents can use the information to improve intertemporal allocation of resources. Epstein, Farhi, and Strzalecki [10] show that in the calibrated long-run risk model, the representative agent is willing to pay more than 30% of her permanent income to resolve all future uncertainty and they argue that this magnitude is implausibly high by introspection. They also state that *"We are not aware of any market-based or experimental evidence that might help with a quantitative assessment"*. Kadan and Manela [26] estimate the value of information in a model with recursive utility. Schlag, Thimme, and Weber [37] find supporting evidence for PER using options market data. Both the above papers assume the CES form of utility function and do not distinguish PER from GRS, or uncertainty aversion.

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[1]For example, in the constant elasticity case, as shown in Ai and Bansal [2], PER is equivalent to risk aversion being higher than IES, which is also equivalent to GRS.

A vast literature applies the above non-expected utility models to the study of asset prices and the equity premium. We refer the readers to Epstein and Schneider [12] for a review of asset pricing studies with the maxmin expected utility model, Ju and Miao [25] for an application of the smooth ambiguity-averse preference, Hansen and Sargent [20] for the robust control preference, Routledge and Zin [35] for an asset pricing model with disappointment aversion, and Bansal and Yaron [4], Bansal [3] and Hansen, Heaton, and Li [19] for the long-run risk model that builds on recursive preferences. Skiadas [38] provides an excellent textbook treatment of recursive preferences based asset pricing theory.

Our empirical results are related to the previous research on stock market returns on macroeconomic announcement days. The previous literature documents that stock market returns and Sharpe ratios are significantly higher on days with macroeconomic news releases in the United States (Savor and Wilson [36]) and internationally (Brusa, Savor, and Wilson [6]). Lucca and Moench [31] find similar patterns and document a pre-FOMC announcement drift. Mueller, Tahbaz-Salehi, and Vedolin [34] document an FOMC announcement premium on the foreign exchange market and attribute it to compensation to financially constrained intermediaries.

The rest of the paper is organized as follows. We begin with a simple example in Section 2 to illustrate the concept of preference for early resolution of uncertainty and generalized risk sensitivity. In Section 3, we develop a thought experiment that allows us to identify PER from risk premiums of claim to market volatility. Building on these theoretical insights, in Section 4, we develop an identification strategy and present evidence for PER based on option prices on S&P 500 index options. Section 5 concludes.

2   PER and GRS

In this section, we illustrate the concept of preference for early resolution of uncertainty and generalized risk sensitivity in a simple three-period model. We also provide simple examples for both properties of preferences.

2.1   Preference for early resolution of uncertainty

Our concept of PER is the same as Kreps and Porteus [29]. Figure 1 provides a simple example of early (top panel) and late (bottom panel) resolution of uncertainty. There are three periods in the model, −1, 0, and 1. The squares represent the consumption in each

period, and the circles represent the agent's information node. The only uncertainty comes in period 1, where consumption can be high (C_H) or low (C_L). The paths of consumption and the probability of outcomes are identical in the top panel and the bottom panel. The only difference is that in the top panel the uncertainty about period 1 consumption is resolved one period in advance — in period 0, whereas in the bottom panel, the uncertainty about period 1 consumption is not resolved until period 1. In period -1, facing the choice between the two alternative consumption plans, an agent who prefers early resolution of uncertainty would chose the plan in the top panel over that in the bottom panel.

Figure 1: **Early and late resolution of uncertainty**
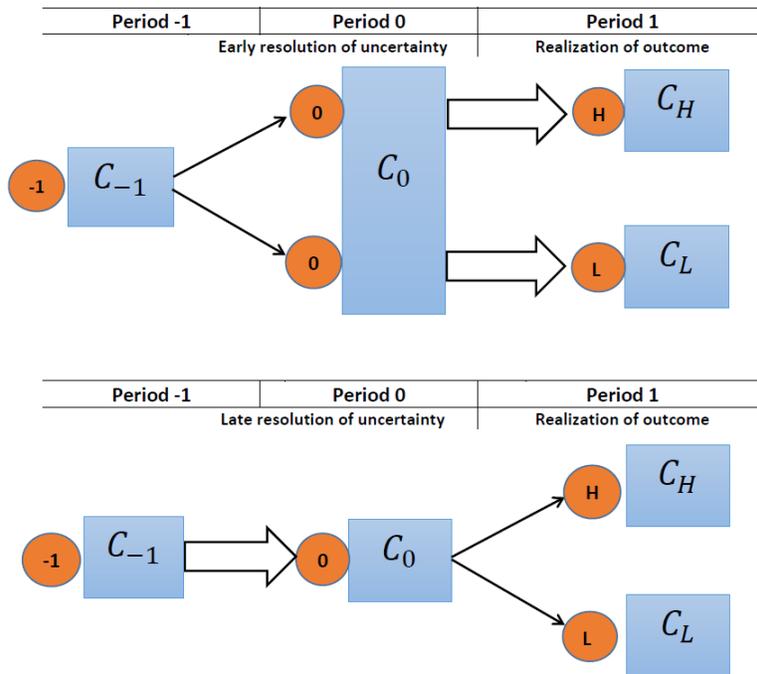

Figure 1 illustrates the notion of PER. Both panels have identical distributions of consumption. The top panel is a situation with early resolution, as the uncertainty about C_1 is resolved one period earlier, in period 0. The bottom panel corresponds to the case of late resolution, because C_1 is not revealed to the consumption until period 1.

To model PER, we use the general formulation of dynamic preferences in Strzalecki [40], where utility at time t, V_t is defined through a recursive relationship:

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

In this setup, dynamic preferences can be represented by a pair $\{u, \mathcal{I}\}$, where u is the Von Neumann–Morgenstern utility function that converts consumption into utility units, and $\mathcal{I}$ is the certainty equivalent functional that aggregates next-period continuation utility, which is a random variable, into its certainty equivalent.

To compute the utility for early resolution (top panel), we first compute investors' utility at time 0. Because uncertainty is fully resolved, we only need to aggregate across time: $V_0 = u(C_0) + \beta u(C_1)$. Going back to period -1, we need to first aggregate next-period utility across uncertain states of the world, $\mathcal{I}[u(C_0) + \beta u(C_1)]$ and then combine it with current-period utility to compute:

$$V_{-1} = u(C_{-1}) + \mathcal{I}[u(C_0) + \beta u(C_1)]. \tag{1}$$

In the case of late resolution (bottom panel), because uncertainty is resolved in period 1, we need first to aggregate over uncertainty states of the world when computing period 0 utility: $V_0 = u(C_0) + \beta \mathcal{I}[u(C_1)]$, and simply aggregate over time in period -1:

$$V_{-1} = u(C_{-1}) + u(C_0) + \beta \mathcal{I}[u(C_1)]. \tag{2}$$

Comparing equations (1) and (2), it is clear that PER can be formulated as the following property of the certainty equivalent functional:

$$\mathcal{I}[u(C_0) + \beta u(C_1)] \geq u(C_0) + \beta \mathcal{I}[u(C_1)]. \tag{3}$$

Below we provide two examples of non-expected utility: one is the constraint robust control preference of Hansen and Sargent [21], which is indifferent toward the timing of resolution of uncertainty. The second example is the recursive utility of Epstein and Zin [13], which features preference for early resolution of uncertainty.

Examples Both preferences can be specified in terms of the $\{u, \mathcal{I}\}$ representation. Let $(\Omega, \mathcal{F}, P)$ be the probability space from which the uncertainty of the economy is generated. The certainty equivalent functional for the robust control preference is written as

$$\mathcal{I}[V] = \min_{m} E[m(\omega) V(\omega)]$$
$$subject\ to: \quad E[m(\omega) \ln m(\omega)] \leq \eta,$$
$$E[m(\omega)] = 1.$$

The above expression can also be interpreted as a special case of the more general maxmin expected utility of Gilboa and Schmeidler [16]. The agent treats the reference probability measure, which is represented by the expectation operator, E, as an approximation. As a result, the agent takes into account of a class of alternative probability measures, represented by the density m, close to the reference probability measure, and evaluates utility using the worst-case probability. The inequality $E[m \ln m] \leq \eta$ requires that the relative entropy of the alternative probability models is less than η.

Under the constraint robust control preference, $\mathcal{I}[u(C_0) + \beta u(C_1)]$ can be written as $\min_m E[m\{u(C_0) + \beta u(C_1)\}]$, and $u(C_0) + \beta \mathcal{I}[u(C_1)] = u(C_0) + \beta \min_m [mu(C_1)]$. Because $u(C_0)$ is a constant, the two minimizing probability density in both case are the same, which we denote m^*. It follows that

$$
\begin{aligned}
\mathcal{I}[u(C_0) + \beta u(C_1)] &= E[m^*\{u(C_0) + \beta u(C_1)\}] \\
&= u(C_0) + \beta[m^* u(C_1)] \\
&= u(C_0) + \beta \mathcal{I}[u(C_1)],
\end{aligned}
$$

and the constraint robust control preference is indifferent toward the timing of resolution of uncertainty.

The recursive utility of constant elasticity can be represented as:

$$
u(C) = \frac{1}{1 - 1/\psi} C^{1-1/\psi}; \quad \mathcal{I}[V] = \frac{1}{1 - \frac{1}{\psi}} \left\{ E\left[\left(\left(1 - \frac{1}{\psi}\right) V \right)^\theta \right] \right\}^{\frac{1}{\theta}},
$$

where $\theta = \frac{1-\gamma}{1-1/\psi}$, γ is risk aversion and ψ is intertemporal elasticity of substitution.[2] The utility for early resolution can be computed as: $\mathcal{I}[u(C_0) + \beta u(C_1)] = \frac{1}{1-1/\psi} \left\{ E\left[\left(C_0^{1-1/\psi} + \beta C_1^{1-1/\psi} \right)^\theta \right] \right\}^{\frac{1}{\theta}}$, and the utility for late resolution is $u(C_0) + \beta \mathcal{I}[u(C_1)] = \frac{1}{1-1/\psi} C_0^{1-\frac{1}{\psi}} + \beta \frac{1}{1-1/\psi} \left\{ E\left[C_1^{\theta(1-1/\psi)} \right] \right\}^{\frac{1}{\theta}}$. It is convenient to apply a monotonic transformation to both equations and write the utility for early resolution as:

$$
E\left[\frac{1}{1-\gamma} \left(C_0^{1-\frac{1}{\psi}} + \beta \left(C_1^{1-\gamma} \right)^{\frac{1}{\theta}} \right)^\theta \right],
$$

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[2]The more popular formulation of recursive utility, $U_t = \left\{ C_t^{1-\frac{1}{\psi}} + \beta \left(E\left[U_{t+1}^{1-\gamma} \right] \right)^{\frac{1-1/\psi}{1-\gamma}} \right\}^{\frac{1}{1-1/\psi}}$, corresponds to the monotonic transformation, $U = \left[\left(1 - \frac{1}{\psi}\right) V \right]^{\frac{1}{1-1/\psi}}$.

and the utility for late resolution as:

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

If we define $f(x) = \frac{1}{1-\gamma}\left(C_0^{1-\frac{1}{\psi}} + \beta x^{\frac{1}{\theta}}\right)^{\theta}$, then utility for early resolution can be written as $E\left[f\left(C_1^{1-\gamma}\right)\right]$, and utility for late resolution can be written as $f\left(E\left[C_1^{1-\gamma}\right]\right)$. It is not hard to show that $f(x)$ is convex if and only $\gamma > \frac{1}{\psi}$. Jensen's inequality therefore implies that the recursive utility prefers early resolution if and only if $\gamma > \frac{1}{\psi}$.

As shown in Strzalecki [40], general characterizations of property (3) in terms of the functional form of $\mathcal{I}$ can be quite complicated. Directly testing the functional form of $\mathcal{I}$ from asset prices seems to be extremely hard. The asset pricing test we propose in this paper takes advantage of the notion of generalized risk sensitivity developed in Ai and Bansal [2], which we briefly review in the following section.

2.2   Generalized risk sensitivity

In order to illustrate the notion of generalized risk sensitivity and its link to asset prices, in this section, we describe a formal setup for the evolution of the uncertainty of the economy. Consider a three-period economy, $t = -1, 0, 1$. For $t = -1, 0, 1$, $\omega_t \in \{\Omega, \mathcal{F}\}$, where $\Omega = \{1, 2, 3, \cdots, n\}$ is a finite probability space with n outcomes, and $\mathcal{F}$ is the associated $\sigma-$field defined in the usual way. The uncertainty in the economy is generated from $\{\Omega, \mathcal{F}\} \times \{\Omega, \mathcal{F}\} \times \{\Omega, \mathcal{F}\}$. Let P be a probability measure on the product space, and we assume equal probability for each outcome: $P(\omega) = \frac{1}{n}$ for $\omega = 1, 2, 3, \cdots, n$. In any period t, investors in the economy observe the history of ω up to time t. As in the previous section, we will assume C_{-1} and C_0 are constants and do not depend on the realization of ω_t. Let $C : \Omega \to R^+$ be a measurable function that maps the states into consumption, the case of early resolution can be conveniently modeled as $C_1 = C(\omega_0)$, that is, C_1 depends only the uncertainty that can be resolved in period 0. The case of late resolution corresponds to $C_1 = C(\omega_1)$, where the uncertainty in consumption does not resolve until in period 1.

In the case of early resolution, one can think of the realization of ω_0 as a simple way to model macroeconomic announcements, as it resolves the uncertainty of consumption in period 1. As shown in Savor and Wilson [36] and Ai and Bansal [2], empirically, a large fraction of the equity market risk premium, more than 55%, is realized roughly thirty trading days with significant macroeconomic announcements. The macroeconomic announcement premium can

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be modeled as follows. Let $X : \Omega \to R$ be payoff function. Let $P_{-1}(X)$ be the period -1 price of a payoff that realizes right after the announcement in period 0. An asset X requires an announcement premium if

$$\frac{E[X(\omega_0)]}{P_{-1}(X)} > R_{f,0},$$

where $R_{f,0}$ is the one-period risk-free interest rate that pays off in period 0. It is convenient to define two random variables, X and Y to be comonotone if for any $\omega, \omega' \in \Omega$, $X(\omega) \geq X(\omega')$ if and only if $Y(\omega) \geq Y(\omega')$, and negatively comonotone if for any $\omega, \omega' \in \Omega$, $X(\omega) \geq X(\omega')$ if and only if $Y(\omega) \leq Y(\omega')$. The following theorem, which is a finite-state version of the Theorem of Generalized Risk Sensitivity in Ai and Bansal [2], links the announcement premium to generalized risk sensitivity.

Theorem 1. *(Theorem of Generalized Risk Sensitivity) Suppose both u and $\mathcal{I}$ are strictly increasing and continuously differentiable, the following statements are equivalent:*

1. *The announcement premium for any asset comonotone with C_1 is (strictly) positive.*

2. *The certainty equivalent functional, $\mathcal{I}$ is (strictly) increasing in second-order stochastic dominance.*

3. *For any continuation utility, $V : \{\Omega, \mathcal{F}\} \to R$, the vector of partial derivatives of $\mathcal{I}$ with respect to V, $\left\{\frac{\partial I[V]}{\partial V(\omega)}\right\}_{\omega=1,2,\cdots,n}$ is (strictly) negatively comonotone with $\{V(\omega)\}_{\omega=1,2,\cdots,n}$.*

In the rest of the paper, we will assume preferences satisfy generalized risk sensitivity. The notion of generalized risk sensitivity is appealing in our setup for two reasons. First, it is motivated by the empirical fact of the macroeconomic announcement premium. Second, it links the level of utility, which is a property of preference, to marginal utilities, which can be conveniently tested from asset prices. In particular, under the assumption of GRS, the ranking of the level of utility is exactly the reverse of the ranking of continuation utility, a property which we exploit in the following sections.

3 An asset pricing test for PER

3.1 A thought experiment

In this section, we propose a thought experiment that identifies PER from asset prices. We combine the scenario of early and late resolution in Figure 1 into one binomial tree and add a period -2. This is illustrate in Figure 2 below.

There are four periods in our thought experiment. As before, the only uncertainty came in period 1, where consumption can be high or low. Period 0 is the period with potential resolution of uncertainty. As in the previous section, we interpret the realization of uncertainty in period 0 as the arrival macroeconomic announcements. For simplicity, we assume that the macroeconomic announcement may be perfectly informative and reveals the true state of the world (top branch of the tree) or may be completely uninformative (bottom branch of the tree).

Period -1 is called the period of *resolution of informativeness*. In this period, the representative agent receives a signal about the informativeness of the announcement: she will realize whether the announcement made in period 0 will be informative or not. In Figure 2, $-1(I)$ represent the node where the announcement in the next period will be informative, and $-1(N)$ represents the node where the announcement in the next period will not be informative. The agent faces the same distribution of future consumption at node $-1(I)$ and at node $-1(N)$. The only difference is that at node $-1(I)$, the agent expects that the uncertainty will be resolved earlier in period 0, whereas at node $-1(I)$, the agent anticipates the upcoming macroeconomic announcement to be completely uninformative about the consumption in period 1. An agent who prefers ER (LR) will have a higher (lower) utility at node $-1(I)$ than at node $-1(N)$.

Our assumption that consumption in period -2, -1, and 0 is constant is designed to capture the fact that macroeconomic announcements and the informativeness of macroeconomic announcements are realized on a few days around the scheduled announcements. The variations in aggregate consumption in a few days is unlikely to account for a quantitatively significant risk premium of any asset. Assume a constant consumption allows us to provide a sharp characterization of the property of the certainty equivalent functional $\mathcal{I}$ in term of asset prices.

Consider the economy in Figure 2. PER implies that the level of utility is higher at node $-1(I)$ than at node $-1(N)$. Under GRS, the marginal utility must be lower at $-1(I)$ than at $-1(N)$. The ranking of marginal utility can be detected from risk premiums: a lower marginal utility at note $-1(N)$ relative to that at node $-1(I)$ is equivalent to the fact that any asset with payoff higher at $-1(I)$ and lower at $-1(N)$ will require a positive risk premium.

The above argument implies that, to empirically identify PER, we need to observe an asset with payoff increasing in the informativeness of upcoming macroeconomic announcements. Intuitively, an informative announcement carries significant news about the future of the economy and is therefore associated with large realizations of stock market volatility. An
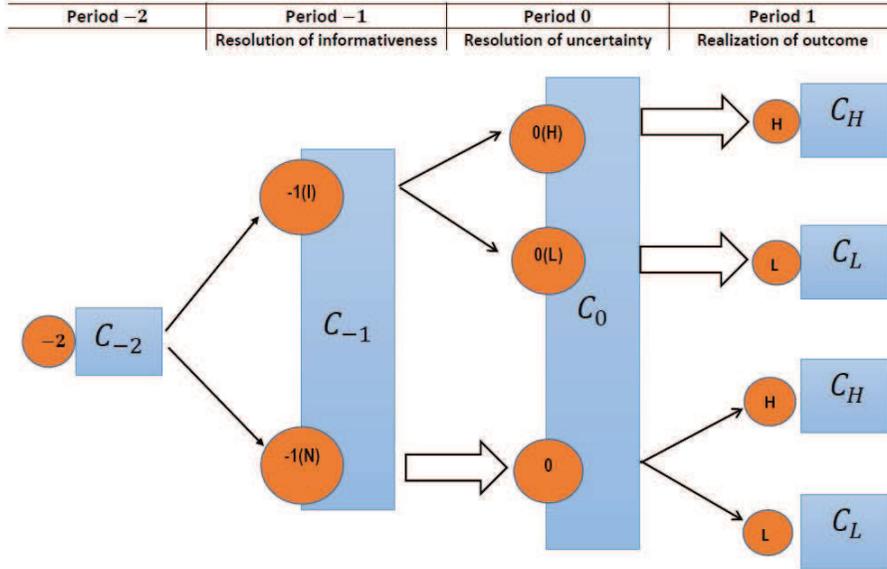
Figure 2: **Resolution of informativeness**

Figure 2 represents our thought experiment of resolution of informativeness. $-1\,(I)$ is node where the agent expects the uncertainty about C_1 to be resolved in period 0 with an informative macroeconomic announcement. Node $-1\,(I)$ represents the situation where the upcoming announcement is expected to be completely uninformative about future.

uninformative announcement, on the other hand, is unlikely to be followed by immediate reactions of the stock market. Therefore, the claims to market volatility is an example of a payoff that is increasing in the informativeness of upcoming macroeconomic announcements.

To summarize, if investors' prefer early(late) resolution of uncertainty, their marginal utility is increasing(decreasing) in the informativeness of upcoming macroeconomic announcements. Because the claim to the market volatility is monotone with respect to the informativeness of announcements, a positive(negative) premium for the claim to market volatility identifies preference for early(late) resolution of uncertainty. Similarly, if investors are indifferent toward the timing of resolution of uncertainty, the continuation utility and therefore the marginal will be the same at node $-1\,(I)$ and at $-1\,(N)$. As a result, the claim to the market volatility should not be compensated by any risk premium. We formalize the above intuition in the following section.

3.2 An equivalence result

The Main Theorem We extend the setup in Section 2.2 to include period -2, as illustrated in 2. We define a random variable $\tau : \Omega \to \{0,1\}$ and specify aggregate consumption of the economy as C_{-2}, C_{-1}, C_0, and $C\left(\omega_{\tau(\omega_{-1})}\right)$. Note that if $\tau\left(\omega_{-1}\right) = 1$, then consumption is not revealed until in period 1. If, on the other hand, $\tau\left(\omega_{-1}\right) = 0$, then consumption in period 1 depends on ω_0, which is fully revealed in period 0. In period -1, although the realization of ω_{-1} does not carry any information about C_1, it reveals the timing the resolution of uncertainty about C_1. The realization of ω_{-1} can therefore be interpreted as resolution of informativeness: $\tau\left(\omega_{-1}\right) = 0$ corresponds to fully informative macroeconomic announcements and $\tau\left(\omega_{-1}\right) = 1$ corresponds to completely uninformative macroeconomic announcement in period 0.

Consider any asset with payoff $X : \Omega \to R$. Let P_{-1} be the price of the asset. We say asset X requires a positive resolution of informativeness premium if

$$\frac{E\left[X\left(\omega_{-1}\right)\right]}{P_{-2}} > R_{f,-1},$$

that is, if the strategy of purchasing the asset right before the resolution of informativeness and selling it right after earns an expected return higher than the risk-free interest rate.

Theorem 2. *Suppose both u and $\mathcal{I}$ are strictly increasing, continuously differentiable and satisfies GRS, the following statements are equivalent:*

1. *The announcement premium for any asset negative comonotone with $\tau\left(\omega_{-1}\right)$ is positive (negative).*

2. *The certainty equivalent functional, $\mathcal{I}$ satisfy preference for early (late) resolution of uncertainty.*

To fix terminology, in what follows, we will call the premium for assets negative comonotone with $\tau\left(\omega_{-1}\right)$ the resolution of informativeness premium.

Examples Here, we provide expressions for the stochastic discount factor that prices assets that pays off during the period of resolution of informativeness for two two examples of GRS preferences we discussed in Section 2.1. The stochastic discount factor that computes the present value of one unit period -1 consumption good measured in terms of period 1 consumption numeraire is $\beta m^*\left(\omega\right)\frac{u'(C_{-1})}{u'(C_{-2})}$. Because the agent is indifferent toward the timing

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of resolution of uncertainty, $V_{-1}(\omega_{-1})$ is equal for all possible realizations of ω_{-1}. As a result, the minimizing probability density and therefore the SDF is not unique. This is an example where the robust control preference allows for multiple market clearing prices.[3]

The SDF for the recursive preference with constant elasticity takes the familiar form of:

$$SDF(\omega_{-1}) = \beta \left(\frac{C_{-1}}{C_{-2}}\right)^{-\frac{1}{\psi}} \left[\frac{U_{-1}(\omega_{-1})}{\left(E\left[U_{-1}^{1-\gamma}(\omega_{-1})\right]\right)^{\frac{1}{1-\gamma}}}\right]^{\frac{1}{\psi}-\gamma},$$

where $U = \left[\left(1-\frac{1}{\psi}\right)V\right]^{\frac{1}{1-1/\psi}}$ is a monotonic transformation of V. Note that the term $\beta\left(\frac{C_{-1}}{C_{-2}}\right)^{-\frac{1}{\psi}}$ is constant and therefore does not depend on ω_{-1}. It is well-known that $\gamma > \frac{1}{\psi}$ corresponds to the case of preference for early resolution of uncertainty. In this case, marginal utility is lower in states of early resolution of uncertainty, that is $SDF(\omega_{-1}) < SDF(\omega'_{-1})$ if $\tau(\omega_{-1}) = 0$ and $\tau(\omega'_{-1}) = 1$. Therefore, any asset positively correlated with the informativeness of announcements should receive a positive premium.

If $\gamma < \frac{1}{\psi}$, then $U_{-1}(\omega_{-1}) < U_{-1}(\omega'_{-1})$ whenever ω_{-1} is early resolution and ω'_{-1} is late resolution. However, because $\frac{1}{\psi} - \gamma > 0$, this stochastic discount factor is also has the property that $SDF(\omega_{-1}) < SDF(\omega'_{-1})$ if $\tau(\omega_{-1}) = 0$ and $\tau(\omega'_{-1}) = 1$. Therefore, any asset positively correlated with the informativeness of announcements should receive a positive premium. Note this example violates the assumption of GRS of Theorem 2. One can show that the $\mathcal{I}$ operator is decreasing in second order stochastic dominance for $\gamma < \frac{1}{\psi}$. A positive resolution of informativeness premium identifies PER only under the assumption of GRS. In this sense, it is the joint test of announcement premium and the resolution of informativeness premium that identifies PER.

4   Empirical evidence

4.1   Key elements for identifying PER

To operationalize our thought experiment and use financial market data to test PER, empirically, we use monetary policy announcements made by the Federal Open Market Committee (FOMC) as our primary example of macroeconomic announcements. In our

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[3]However, if we require that small perturbation of continuation utility does not lead to large changes in prices, then the unique m^* that survives this criteria is $m^* = 1$, that is there is no probability distortion. This choice is associated with zero risk premium on any asset.

thought experiment, the test for PER boils down to a test for the sign of the risk premium on claims to stock market volatility ahead of macroeconomic announcements. In the context of FOMC announcements, we need the following elements to establish a period of resolution of informativeness:

1. The informativeness of FOMC announcements must change over time. In the language of the thought experiment, more informative FOMC announcements lead to early resolution of uncertainty and less informative ones to late resolution of uncertainty.

2. Such heterogeneity in the informativeness must be perceived by the market. That is, the market must be able to distinguish early resolution (node $-1\,(I)$ in Figure 2) from late resolution (node $-1\,(N)$) so that they can affect asset prices, in particular, the prices of claims to market volatility.

3. The period during which the informativeness of the upcoming FOMC announcements is perceived by the market is the period of resolution of informativeness.

Below, we briefly summarize our identification strategy for each of the above elements.

Variations in the informativeness   To confirm our intuition that the informativeness of FOMC announcements can be measured by the implied volatility reduction over announcements, empirically, we need to show that i) implied volatility of the stock market index (S&P500 index) on average drops over FOMC announcements, and ii) there is substantial variation in such reduction. Implied volatility calculated from options that expire shortly after the announcements is an effective way to measure the informativeness of the announcements.

Predictability of informativeness   Our key identification test for PER is that the informativeness of macroeconomic announcements affects the marginal utility of investors. This requires that the informativeness of announcements to be perceived by the market. We establish this empirically by showing that the amount of reduction in implied volatility is predictable by market prices. In particular, we use the ratio of short-term versus long-term implied volatility, or the inverse slope of the term structure of implied volatility, as a predictor for the implied volatility drop. Our inverse slope variable is defined as:

$$Inv\_Slope = \frac{IV^9}{IV^{90}}, \tag{4}$$

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where IV^9 is the short-term implied stock market volatility, which we measure by using the implied volatility index with 9 days to maturity published by CBOE. IV^{90} is long-term implied volatility measured by the implied volatility index with 90 days to maturity.

Implied volatility from option prices may be affected by changes in the volatility of economic fundamentals (such as the volatility of aggregate productivity shocks) or by the informativeness of macroeconomic news. Variations in the volatility of economic fundamentals presumably happen at a much lower frequency than the few days of macroeconomic announcements. Fundamental economic volatility is therefore likely to affect both short-term and long-term volatility. The inverse slope constructed above allows us to control for volatility of economic fundamentals and better predict the informativeness of announcements. We show in the next section that Inv_Slope has significant predictive powers for the implied volatility reduction on macroeconomic announcement days.

Resolution of informativeness The resolution of informativeness premium in our thought experiment is obtained through a strategy that purchases aggregate volatility before the resolution of informativeness and sells right afterwards. In the data, therefore, we need to identify a period in which the informativeness of announcements are realized on the market. Note that the inverse slope variable can be written as a sum of an initial condition and changes over time:

$$Inv\_Slope_{t-1} = \sum_{j=1}^{J-1} \Delta Inv\_Slope_{t-j} + Inv\_Slope_{t-J},$$

where $\Delta Inv\_Slope_{t-j} = Inv\_Slope_{t-j} - Inv\_Slope_{t-j-1}$ is the change in inverse slope from $t-j-1$ to $t-j$. If we set the initial date $t-J$ distant enough from the announcement date, the predictability of Inv_Slope_{t-1} for the informativeness of FOMC announcements must come from a subset of days between $t-J$ and $t-1$. These are the days in which the informativeness of announcements are realized by the market. Empirically, we use regression analysis to identify the period of resolution of informativeness as the days in which the changes in slope have significant predictive power for the reduction of short-term market volatility. We show in the next section that evidence suggests that this typically corresponds to the five or six weekdays before the announcements.

Premium for claims to market volatility Having identified the period of resolution of informativeness, our final step is to estimate the risk premium earned on claims to short-

term market volatility during this period. Britten-Jones and Neuberger [5] and Jiang and Tian [24] show that under appropriate assumptions, stock market return volatility can be constructed from option prices. We use R_τ to denote stock return from time 0 to time τ, $P_{0,\tau}(K)$ and $C_{0,\tau}(K)$ to denote time-0 price of a put option and that of a call option, respectively, with maturity T and strike price K, then

$$Var\left[\ln R_\tau\right] = \frac{2e^{r\tau}}{\tau} \left\{ \int_0^{F_{0,\tau}} \frac{1}{K^2} P_{0,\tau}(K)\, dK + \int_0^{F_{0,\tau}} \frac{1}{K^2} C_{0,\tau}(K)\, dK \right\}.$$

Empirically, we can use the weighted sum of options with different strikes to approximate the above integral and construct the claims to aggregate volatility. If the maturity is thirty days, the construction of the portfolio implied by this procedure is exactly the same as the portfolio used to construct the VIX index. We empirically estimate the excess return of this portfolio during the period of resolution of informativeness. Our Theorem 2 implies that an extra positive (negative) average return during the period of resolution of informativeness is indicative of investors' preference for early (late) resolution of uncertainty.

4.2   Resolution of informativeness

In this section, we document our empirical evidence for investors' preference for the timing of resolution of uncertainty using data from the options market. The implied volatility data we use include the 9-day, 30-day (VIX), and 90-day implied volatility indices on S&P 500 from CBOE. The 30-day implied volatility is the VIX index, which goes back to 1990. The 9-day and 90-day IV indices have shorter history going back to 2011 and 2007 respectively. All of our sample ends in September of 2018. The option return data come from OptionMetrics and go from 1996 to 2017. The 9-day implied volatility has the shortest maturity and is the best measure of the informativeness of FOMC announcements. It however, has the shortest history. In what follows, we present our evidence using both the 9-day implied volatility and the 30-day implied volatility (VIX) as the latter has the longest time series available.

Reductions in implied volatility across announcements   We first show that on average there is a significant reduction in implied volatility on FOMC announcement days. The reduction in implied volatility is quite robust across all maturities. Because the implied volatility for 30-day options, i.e. the VIX index, has the longest time series, we present our evidence here using the VIX index. In figure 3, we plot the level log VIX index around FOMC announcement days with the announcement-day log VIX normalized to zero. We denote the
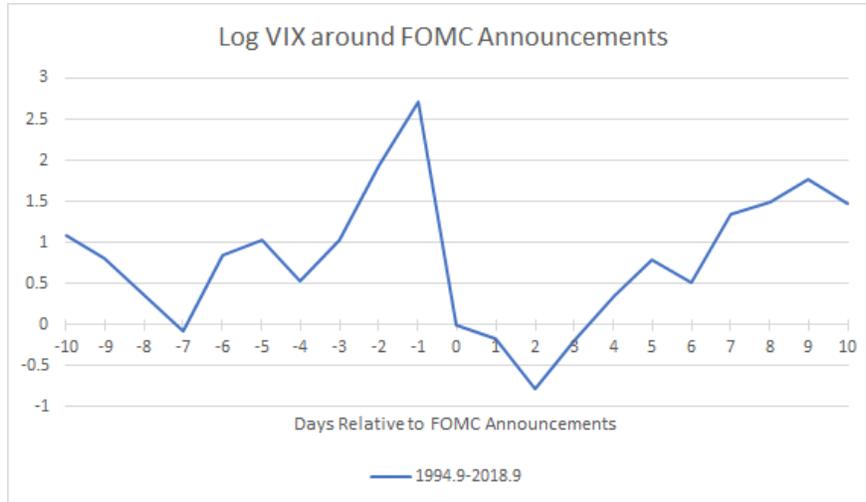
16

Figure 3: **Log VIX around FOMC announcements**

Figure 3 illustrates the average log VIX index around FOMC announcements. We normalize the (end-of-day) log VIX index to zero for the FOMC announcement day. The FOMC announcement day is normalized as day 0, and all other days are labeled relative to the FOMC announcement day.
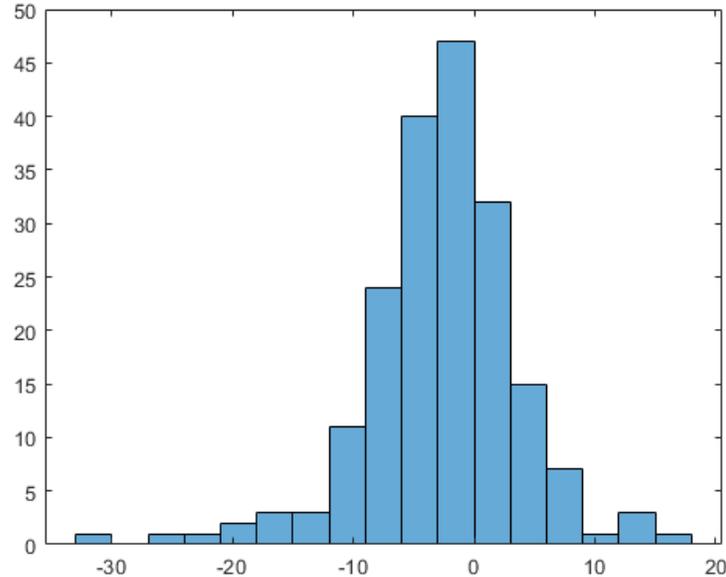
FOMC announcement day as day 0, the day before the announce day as -1, and the day after as 1, etc. All values of the VIX are computed as its end-of-the-day value. There is a clear reduction in VIX on FOMC announcement days. In Table 1, we present a formal regression analysis for the reduction in the VIX index on announcement days controlling for the day-of-the-week effect.[4] The third column is the reduction in 30-day implied volatility and the fourth column is the reductions in 9-day implied volatility. The reduction in VIX on announcement days is significant with a point estimate -2.04%. Because VIX index is the average volatility of 30 days, under the assumption that stock returns are i.i.d., an -2.04% reduction roughly corresponds to a 50% higher volatility on announcement days relative to non-announcement days.[5] The estimate for 9-day implied volatility shows a similar pattern.

There is also substantial variation in the amount of volatility reduction across announcements. We plot the histogram for the changes in VIX index on FOMC

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[4]As shown in Table 1, the VIX index has a significant day-of-week pattern. In particular, changes in VIX is typically positive on Mondays and negative on Wednesday and Fridays. Because FOMC announcements typically occur on Tuesdays and Wednesdays, it is important to control for the day-of-the-week effect.

[5]Assume that the daily volatility is σ on non-announcement days and $(1+x)\sigma$ on announcement days. The thirty-day volatility before announcement is $\sqrt{(1+x)^2 \sigma^2 + 29\sigma^2}$, and the thirty-day volatility after announcement is $\sqrt{30\sigma^2}$. A log difference of 2% between the above translates into a value of $x = 49\%$.

Figure 4: **Histogram of changes in log VIX around FOMC announcements**

This figure plots the histogram of changes in log VIX around FOMC announcements. Changes in log VIX is computed as the difference between the VIX index at the end of the announcement day and that on the day before the announcement day.

announcement days in Figure 4. There is a fairly wide range of volatility reduction across announcements, indicating the informativeness of announcements does change over time. More importantly, as we will show in the next section, these changes are predictable by market prices, in particular, the term structure of implied volatility ahead of announcements.

Predictability of informativeness Next, we demonstrate that the reduction of volatility across announcements can be predicted by the inverse slope of the term structure of implied volatility. We regress the changes in short-term implied volatility on the inverse slope of the previous day, a FOMC announcement day dummy, an interaction between the two terms, and control variables such as the day-of-the-week dummies.

$$\Delta \ln IV_t = \xi_0 + \xi_1 Inv\_Slope_{t-1} + \xi_2 I_t^{FOMC} + \xi_3 Inv\_Slope_{t-1} \cdot I_t^{FOMC} + \sum_{d=1}^{5} \delta_d I_{d,t}^{DOW} + \varepsilon_t. \quad (5)$$

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Here, $\Delta \ln IV_t$ is the one day change in implied volatility from $t-1$ to t, Inv_Slope_{t-1} is the inverse slope defined in (4) on day $t-1$, and I_t^{FOMC} is an indicator variable that takes a value of 1 only if date t is a pre-scheduled FOMC announcement. For $d = 1, 2, \cdots, 5$, $I_{d,t}^{DOW}$ is an indicator variable that take a value of 1 only if time t is the dth day of the week. As explained earlier, we expect short-term volatility to be higher relative to long-term volatility ahead of informative FOMC announcements, because higher informativeness of announcements, if expected by the market, should be associated with larger reactions of stock market returns with respect to these announcements.

In Table 2, we report several versions of the above regression to demonstrate the predictability of announcement-day volatility reductions. In column 1, the regression of volatility reduction on inverse slope produces a significant coefficient of -8.40, indicating that in general, the inverse slope variable has significant predictive powers for volatility reductions. It is well known that volatility is mean reverting. As shown in column 2, higher volatility on the previous day is associated with significantly larger volatility reductions as well. However, whenever the inverse slope variable is included (column 3, 4 and 5), the effect of the level of volatility on the previous day is subsumed. The regression in column 4 includes only the 61 observations on FOMC announcement days. In this case, the effect of inverse slope is much large in magnitude, although the t-statistic is much smaller due to a much smaller sample. In column 5, we report the result of the full regression. Here, Inv_Slope_{t-1} has significant predictive powers for implied volatility reductions in general. More importantly, the coefficient on the interaction term of FOMC indicator and Inv_Slope_{t-1} is significantly larger, indicating the Inv_Slope_{t-1} variable has extra predictive powers on FOMC announcement days. In the last column of the same table, we report the results of regression (5), where the dependent variable is the reduction in 9-day implied volatility. This regression shows a similar pattern with a slightly larger point estimate for ξ_3.

Due to sample limitation, we have only 61 FOMC announcements during the period in which both the 9-day and the 90-day implied volatility are available. As a result, the t-statistic on the estimate is understandably weak: -1.77 for 30-day implied volatility and -2.05 for 9-day implied volatility. As we will show in the next section, when we decompose the slope variables Inv_Slope_{t-1} into changes, the regression coefficient on days close to the announcements, which we identify as the period of resolution of informativeness, is larger and much more significant. This further supports our hypothesis that reductions in implied volatility is predictable.

Period of resolution of informativeness Our predictive variable Inv_Slope_{t-1} can be decomposed into changes in the slope days before the announcement. Here, we identify a period of resolution of informativeness using the predictability regression (5) with Inv_Slope_{t-1} being replaced by changes in inverse slope on days leading up to the FOMC announcements:

$$\Delta \ln IV_t = \xi_0 + \Sigma_{j=1}^{30}\xi_{1,j}\Delta Inv\_Slope_{t-j} + \xi_2 I_t^{FOMC} + \Sigma_{j=1}^{30}\xi_{3,j}\Delta Inv\_Slope_{t-j} \cdot I_t^{FOMC} + \sum_{d=1}^{5} \delta_d I_{d,t}^{DOW} + \varepsilon_t,$$

Because including further lags does not add to the predictive power of the above regression, we report the our regression results with $J = 10$ in Table 3. Here, we include two different regressions, where the dependent variable $\Delta \ln IV_t$, is measured by the reduction of implied volatility with 30 day maturity ($\Delta \ln VIX$ in the table) and that with 9 day maturity ($\Delta \ln VIX9$ in the table), respectively. Across both regressions, the regression coefficient is significant for the changes in inverse slope occurred one, two, and five weekdays before the announcement. The changes in the inverse slope occurred six weekdays before the announcement is significant for the reduction in the VIX index, but not for that in the 9-day implied volatility. Overall, the evidence for the predictability of volatility reduction is quite strong when we focus on changes in inverse slope up to five weekdays before the announcement. We will use the five consecutive weekdays before the announcements as our benchmark measure of the period of resolution of informativeness in the rest of our analysis.

4.3 The PER premium

Theorem 2 implies that the premium received on the claim to market volatility realized during the period of resolution of informativeness must be a premium due to preference for early resolution of uncertainty. To estimate the sign of this PER premium, we construct synthesized variance swaps on S&P 500 index using put and call prices from OptionMetrics, the range of which is 1996 to 2017. The synthesized variance swaps are portfolios of out-of-money puts and calls using exactly the construction methodology of the VIX index. With daily returns to these variance swaps, we run the following regression:

$$r_{\tau,t} = \sum_{a=-10}^{10} \beta_a I_{a,t}^{FOMC} \cdot I_t^{After}(\tau) + \sum_{w=1}^{9} \gamma_w I_{w,t}^{Maturity}(\tau) + \sum_{d=1}^{5} \delta_d I_{d,t}^{DOW} + \epsilon_{\tau,t}. \qquad (6)$$

This is a panel regression where $r_{\tau,t}$ is the log return realized on date t on a claim to market volatility constructed using an option portfolio with maturity τ. $I_a^{FOMC}(t)$ is an indicator function that takes a value of 1 only if date t is a days before a pre-scheduled FOMC announcement. $I^{After}(\tau)$ is an indicator function that take a value of 1 only if the options expire after the announcement. Because the price of options that expire before announcements will not be affected by the informativeness of these announcements, we focus only on options that expire after the announcements. We also include several control variables in the above regression: $I_w^{Maturity}(\tau)$ is an indicator function for the maturity of the options, which takes a value of 1 only if the option is w weeks to maturity, for $w = 1, 2, \cdots, 9$. As before, $I_{d,t}^{DOW}$ are indicator variables that control for the day of the week effect.

We present our regression results in Table 4, where we report the coefficients β_a for $a = 0$ and over the period of resolution of informativeness. Column (1) reports a regression uses all option portfolios with a maturity of less than ten weeks. Column (2) reports the same regression including only options with a maturity of less than six weeks, which guarantees that no options span two consecutive FOMC announcements. The sum of these coefficients for the period of resolution of informativeness, that is, the five days right before announcements, is 10.62%, that is, compared to an average five-day period, the claim to the market volatility earns an extra return of 10.62% during the days of resolution of informativeness. If we use the six-day period before announcements as the period of resolution of informativeness, the point estimate of this excess return is slight larger, 11.39, but the p-value is higher. Overall, our evidence suggests that claims to market volatility earn positive premiums during the period of resolution of informativeness, which is consistent with a preference for early resolution premium.

5   Conclusion

This paper develops a revealed preference theory for preference for the timing of resolution of uncertainty based on asset pricing data and present corresponding empirical evidence. Our main theorem provides an equivalent characterization of the representative agent's preference for early resolution of uncertainty in terms of the risk premium of assets realized during the period of resolution of informativeness of macroeconomic announcements. Empirically, we found support for preference for early resolution of uncertainty based on evidence on the dynamics of the implied volatility of S&P 500 index options around FOMC announcements.

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Table 1

Changes in VIX on FOMC announcement days

	(1)	(2)	(3)	(4)
	$\Delta \ln VIX$	$\Delta \ln VIX$	$\Delta \ln VIX$	$\Delta \ln VIX9$
I_1^{DOW}	1.87***		1.87***	5.68***
	[9.86]		[9.86]	[7.67]
I_2^{DOW}	-0.29*		-0.14	0.15
	[-1.78]		[-0.85]	[0.28]
I_3^{DOW}	-0.44***		-0.28*	-.53
	[-2.86]		[-1.82]	[-0.84]
I_4^{DOW}	-0.11		-0.10	-.93
	[-0.67]		[-0.62]	[-1.55]
I_5^{DOW}	-0.92***		-0.92***	-3.49***
	[-5.32]		[-5.30]	[-5.73]
I_{FOMC}		-2.32***	-2.04***	-3.52***
		[-5.13]	[-4.36]	[-2.16]
Obs	7,231	7,231	7,231	1,936
R^2	0.021	0.004	0.024	0.059

This table reports results from running the following daily time series regression: $\Delta \ln IV_t = \sum_{d=1}^{5} \delta_d I_{d,t}^{DOW} + \xi I_t^{FOMC} + \epsilon_t$, where $\Delta \ln IV_t$ is the change in $\ln VIX$ on day t (in percentage unit), $I_{d,t}^{DOW}$ is the indicator of whether day t is the dth weekday, and I_t^{FOMC} is the indicator of whether day t is a FOMC announcement day. Dependent variable in column (1) is based on the 30 day VIX, and that in column (2) is based on the 9 day VIX. T-statistics are computed with White standard errors and reported in square brackets.

Table 2

Predictability of implied volatility reduction on FOMC announcement days

	(1)	(2)	(3)	(4)	(5)	(6)
	$\Delta \ln VIX$	$\Delta \ln VIX$	$\Delta \ln VIX$	$\Delta \ln VIX$	$\Delta \ln VIX$	$\Delta \ln VIX9$
Inv_Slope_{t-1}	-8.40***		-6.67***	-22.04*	-7.71***	-17.91***
	[-4.38]		[-2.62]	[-1.73]	[-4.02]	[-6.66]
VIX_{t-1}		-0.18***	-0.07	0.02		
		[-4.73]	[-1.35]	[0.06]		
I_{FOMC}					10.64	14.57*
					[1.59]	[1.88]
$Inv\_Slope_{t-1} \cdot I_{FOMC}$					-13.59*	-18.24**
					[-1.78]	[-2.05]
DOW Indicators	Yes	Yes	Yes	No	Yes	Yes
Constant	No	No	No	Yes	No	No
Obs	1,936	1,936	1,936	61	1,936	1,936
R^2	0.038	0.031	0.040	0.166	0.042	0.107

The column (5) of this table reports results from running the following daily time-series regression: $\Delta \ln IV_t = \xi_0 + \xi_1 Inv\_Slope_{t-1} + \xi_2 I_t^{FOMC} + \xi_3 Inv\_Slope_{t-1} \cdot I_t^{FOMC} + \sum_{d=1}^{5} \delta_d I_{d,t}^{DOW} + \varepsilon_t$, where $\Delta \ln IV_t$ is change in log VIX on day t (in percentage unit), Inv_Slope_{t-1} is the inverse slope on day $t-1$, I_t^{FOMC} is the indicator of whether day t is a FOMC day, and $I_{d,t}^{DOW}$ are indicators of whether day t is the dth weekday. Column (1) to (3) are the regression with subsets of the independent variables and possibly adding VIX_{t-1} which is the VIX level of day $t-1$. Column (4) is restricted to FOMC announcement days only. Column 6 has a different dependent variable which is change in 9-day VIX. T-statistics are computed with White standard errors and reported in square brackets.

Table 3

Predictability of volatility reduction with lags

	(1)		(2)	
	$\Delta \ln VIX$		$\Delta \ln VIX9$	
	Coef	T-stat	Coef	T-stat
$\xi_{3,1}$	-50.22***	[-3.56]	-56.31***	[-3.02]
$\xi_{3,2}$	-33.61***	[-2.89]	-42.81***	[-2.76]
$\xi_{3,3}$	-17.16	[-1.35]	-16.10	[-0.92]
$\xi_{3,4}$	-0.13	[-0.01]	-11.82	[-0.55]
$\xi_{3,5}$	-55.92***	[-2.97]	-67.63**	[-2.51]
$\xi_{3,6}$	-40.66**	[-2.34]	-33.82	[-1.39]
$\xi_{3,7}$	-17.15	[-1.50]	-24.24	[-1.47]
$\xi_{3,8}$	-15.33	[-1.20]	-25.89	[-1.33]
$\xi_{3,9}$	-5.14	[-0.34]	-2.99	[-0.14]
$\xi_{3,10}$	14.49	[0.72]	11.76	[0.38]
DOW Indicators	Yes		Yes	
FOMC Indicator	Yes		Yes	
Constant	No		No	
Obs	1,906		1,906	
R^2	0.064		0.121	

The table reports the results from the following daily time-series regression: $\Delta \ln IV_t = \xi_0 + \Sigma_{j=1}^{30} \xi_{1,j} \Delta Inv\_Slope_{t-j} + \xi_2 I_t^{FOMC} + \Sigma_{j=1}^{30} \xi_{3,j} \Delta Inv\_Slope_{t-j} \cdot I_t^{FOMC} + \sum_{d=1}^{5} \delta_d I_{d,t}^{DOW} + \varepsilon_t$, where $\ln IV_t$ is the change of log VIX on day t (in percentage unit), ΔInv_Slope_{t-j} is the change of the inverse slope on day $t-j$, I_t^{FOMC} is the indicator of whether day t is a FOMC announcement day, and $I_{d,t}^{DOW}$ are indicators of whether day t is the dth weekday. Dependent variable is computed with the 30 day VIX for column (1), and the 9 day VIX for column (2). T-stats are computed using White standard errors and reported in square brackets on the side of the coefficient values.

Table 4

Excess returns of options during the period of resolution of informativeness

	(1)	(2)
	10 weeks	6 weeks
β_0	-3.57***	-3.75**
p-value	0.009	0.023
$\sum_{a=-1}^{-5}\beta_a$	8.49**	10.62**
p-value	0.048	0.031
$\sum_{a=-1}^{-6}\beta_a$	9.08*	11.39**
p-value	0.065	0.042
Obs	28,893	19,891
R^2	0.107	0.117

This table reports the results of the following panel regression $r_{\tau,t} = \sum_{a=-10}^{10} \beta_a I_{a,t}^{FOMC} \cdot I_t^{After}(\tau) + \sum_{w=1}^{9} \gamma_w I_{w,t}^{Maturity}(\tau) + \sum_{d=1}^{5} \delta_d I_{d,t}^{DOW} + \epsilon_{\tau,t}$, where $r_{\tau,t}$ is the log return of the option portfolio with expiration τ on day t (in percentage unit), $I_{a,t}^{FOMC}$ is an indicator of whether day t is a weekdays away from a FOMC announcement day, $I_t^{After}(\tau)$ is an indicator of whether τ is after the next FOMC announcement as of day t, $I_{w,t}^{Maturity}(\tau)$ is an indicator of whether t is within w weeks of τ, and $I_{d,t}^{DOW}$ is an indicator of whether day t is the dth weekday. Results in column (1) are computed on the full sample of options, which are up to 10 weeks from their expiries, and those in column (2) are computed on the subsample of options expiring in 6 weeks. T-stats are computed using clustered standard errors by date (i.e. t) and reported in square brackets on the side of the coefficients.