Information-Driven Volatility

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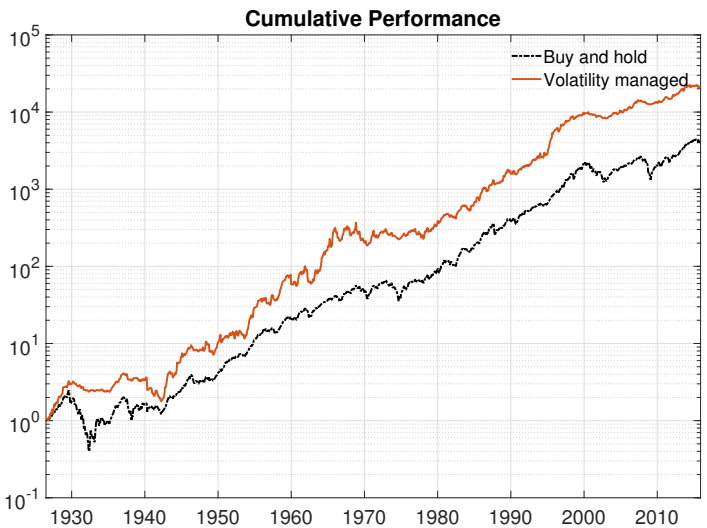
Volatility and Expected Return Relationship

- Standard stochastic volatility models imply a positive correlation between *past realized volatility* and *future expected returns*
- Empirical evidence often finds a negative correlation
- This paper: a theory of information-driven volatility
  - negative correlation between past realized volatility and future expected returns
  - several other volatility related puzzles

Evidence for Negative Predictability

- Negative corr between realized volatility and expected returns
  - Nelson (1991); Glosten, Jagannathan, Runkle (1993)

- Volatility managed portfolio (Moreira and Muir, 2017)
  - Raise (lower) leverage on market when realized vol is low (high)
  - produces an average return, 1.8% higher than the market



Realized and Expected Volatility

- No arbitrage implies: $\mathbb{E}_t[R_{t+1}] - r_f = -r_f \text{Cov}[SDF_{t+1}, R_{t+1}]$, thus

$$\underbrace{\mathbb{E}_t[R_{t+1}] - r_f}_{\text{future expected return}} = \underbrace{r_f \times (-\rho) \times \sigma_t(SDF_{t+1})}_{>0} \quad \underbrace{\sigma_t(R_{t+1})}_{\text{future expected vol}}$$

- "Positive risk-return trade-off"
- Standard models: time-varying vol of macro fundamentals
  - vol is positively auto-correlated
  - past realized vol positively predicts future expected vol
  - $\Rightarrow$ and therefore positively predicts future expected returns
- Information-driven volatility:
  - past realized vol negatively predicts future expected vol
  - and therefore negatively predicts future expected returns

Information-Driven Volatility

- Volatility can be driven by fundamentals or information s_t

$$\text{Var}\left[\theta_T\right] = \underbrace{\text{Var}\left[\mathbb{E}\left(\theta_T|s_t\right)\right]}_{\text{past realized vol}} + \underbrace{\mathbb{E}\left[\text{Var}\left(\theta_T|s_t\right)\right]}_{\text{future expected vol}} \quad (1)$$

- Traditional stochastic vol model: shocks to $\text{Var}\left[\theta_T\right]$ directly
- Keep total volatility $\text{Var}\left[\theta_T\right]$ fixed:
  - More precise info $s_t \Rightarrow \text{Var}\left[\mathbb{E}\left(\theta_T|s_t\right)\right] \nearrow \Rightarrow \text{Var}\left(\theta_T|s_t\right) \searrow$
  - Information-driven volatility induces a negative correlation
- Key difference between our model and traditional models
  - sources of shocks: $\text{Var}[\theta_T]$ or $\text{Var}[s_t]$?
  - risk premium for $\text{Var}[s_t]$?

Summary of Results

- High frequency financial market fluctuations is more likely to be driven by information
- High informativeness $\Rightarrow$ high variance of announcement day return, low variance in the future
- Under strong generalized risk sensitivity (GRS),
  high informativeness $\Rightarrow$ high risk premium upon announcements,
  low risk premium in the future
- $\Rightarrow$ A negative corr between realized variance on announcement day and future expected return

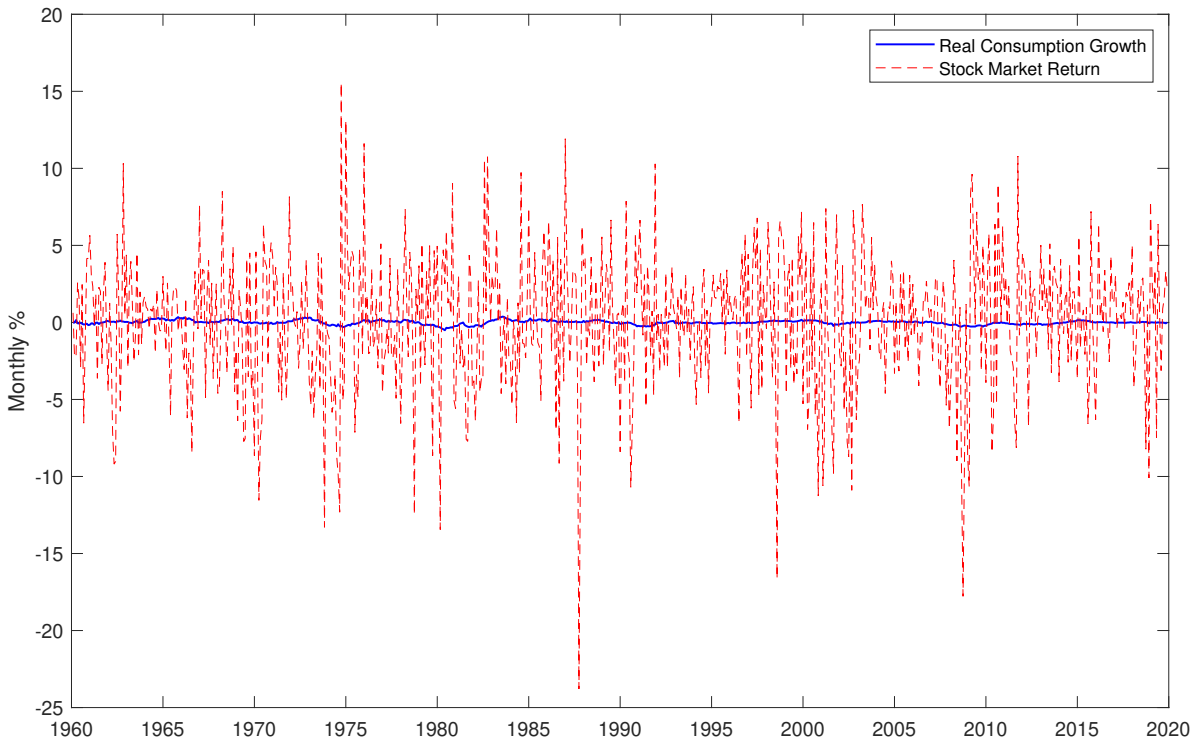
Literature

- Volatility and expected return relationship
  - French, Schwert, Stambaugh (1987); Nelson (1991); Glosten; Jagannathan, Runkle (1993); Harvey (1989), Harrison and Zhang (1999); Moreira and Muir (2017); Follett, Kou, Stuart, Yu (2022)
- Macroeconomic announcement premium
  - Savor and Wison (2013, 2014); Lucca and Moench (2015); Hu, Pan, Wang, and Zhu (2021); Ai and Bansal (2018)
- Learning and asset pricing
  - David (1997); Veronesi (2000); Ai (2010); Bansal and Shaliastovich (2010); Shaliastovich (2015)
- Variance risk premium
  - Bollerslev, Tauchen, and Zhou (2009); Drechsler and Yaron (2011); Eraker and Wang (2015); Zhou (2018); Bakshi, Crosby and Gao (2022).

Motivating Facts for Information-Driven Vol

Premise 1: Information Drives High-Frequency Vol

- Over short horizons (daily, weekly, monthly), stock market volatility is more likely to be driven by information



Premise 2: Info Driven Vol Requires a Risk Compensation

- Info-driven vol requires a risk compensation⇒return predictability
- Empirical support: macro announcement premium
  - Large fraction of equity premium is realized on a small number of trading days with significant macro-announcements.

1961-2021	# days	daily prem.	Prem P.a.
Market	247	3.76 *bps*	9.29%
Ann.	48	14.05 *bps*	6.75%
No Ann.	199	1.28 *bps*	2.54%

- Theory: Ai and Bansal (2018): existence of announcement premium implies generalized risk sensitivity (GRS)
- Strong GRS ⇒ info-driven vol generates return predictability

Theory of Information-Driven Volatility

Theory of Information-Driven Volatility

Timing of events

Time	0	t (*announcement*)	T
Vague announcement			
Information	0	$s_t = \eta$	θ_T
Informative announcement			
Information	0	$s_t = (\eta, \varepsilon)$	θ_T

- Information precision: $\eta \subseteq (\eta, \varepsilon) \subseteq \theta_T$

Theory of Information-Driven Volatility

Information and variance

- The variance decomposition formula implies:
  - variance in the announcement return

$$\text{Var}\left(\mathbb{E}\left[\theta_T \middle| \eta, \varepsilon\right]\right) \geq \text{Var}\left(\mathbb{E}\left[\theta_T \middle| \eta\right]\right), \tag{2}$$

  - variance in the post-announcement return

$$\mathbb{E}\left[\text{Var}\left(\theta_T \middle| \eta, \varepsilon\right)\right] \leq \mathbb{E}\left[\text{Var}\left(\theta_T \middle| \eta\right)\right]. \tag{3}$$

- More precise information $\Leftrightarrow$ higher variance at announcement and lower variance after announcement

Information and SDF

Preferences

- Representative agent, continuous-time endowment economy
- Utility representation:

$$V_\tau = \left(1 - e^{-\rho\Delta}\right) u\left(Y_\tau\right) + e^{-\rho\Delta}\mathcal{I}\left[V_{\tau+\Delta}\right], \tag{4}$$

- Certainty equivalent:

$$\mathcal{I}\left[V\right] = \phi^{-1}\left(\mathbb{E}\left[\phi(V)\right]\right) \tag{5}$$

- Ai and Bansal (2018): the existence of announcement premium implies GRS $\rightarrow \phi$ is strictly increasing concave

Strong Generalized Risk Sensitivity

- Definition of GRS: ϕ is strictly increasing concave

$$-\frac{\phi''}{\phi'} \geq 0. \tag{6}$$

- Definition of strong GRS:

$$-\frac{\phi''}{\phi'} \geq \sqrt{\frac{1}{2}\frac{\max\{\phi''', 0\}}{\phi'}}. \tag{7}$$

- Definition of entropy of the SDF:

$$\mathcal{H}(SDF) = \mathbb{E}[-\ln SDF]$$

  - measures the variability of SDF
  - motivation: $\mathcal{H}(SDF) \geq \mathbb{E}[\ln R]$ for all R
  - compare expected return $\Leftrightarrow$ compare entropy

SDF and Risk Premium

Assume strong GRS, then informative announcement economy has:

- a higher entropy (more volatile) of the announcement SDF:

$$\mathcal{H}\left[SDF\left(0,\left(\eta,\varepsilon\right)\right)\right] \geq \mathcal{H}\left[SDF\left(0,\eta\right)\right], \tag{8}$$

- a lower entropy (less volatile) of post-announcement SDF:

$$\mathcal{H}\left[SDF\left(\left(\eta,\varepsilon\right),\theta_T\right)\right] \leq \mathcal{H}\left[SDF\left(\eta,\theta_T\right)\right]. \tag{9}$$

- More precise information $\Leftrightarrow$ higher expected return at announcement and lower expected return afterward

The Dynamic Model

A Dynamic Model with Time-Varying Info Quality

Model Setup

- Rep agent, Epstein-Zin preference, IES ψ and risk aversion γ
  - strong GRS implies $\gamma > 1 > \frac{1}{\psi}$. (GRS: $\gamma > \frac{1}{\psi}$)
- Consumption dynamics

$$\frac{dY_t}{Y_t} = \theta_t dt + \sigma_Y dB_{Y,t},$$

- *Unobserved* two-state Markov chain: $\theta_t \in \{\theta_H, \theta_L\}$
- Consumption vol is σ_Y is constant

A Dynamic Model with Time-Varying Info Quality

Two sources of information about θ_t

1. Aggregate consumption itself contains info about θ_t
2. Announcements: a public signal s_t at time $T, 2T, \cdots$
   - s_t reveals the true value of θ_t with probability $\nu \in [0.5, 1]$
   - $\nu = 1$: fully revealing; $\nu = 0.5$: completely uninformative

- ν is i.i.d. over time
  - time-varying informativeness of announcements
- $\hat{\theta}_t$: posterior belief of θ_t after learning

A Dynamic Model with Learning

Dividends

- Dividend dynamics

$$\frac{dD_t}{D_t} = \left[\xi\left(\hat{\theta}_t - \bar{\theta}\right) + \bar{\theta}\right] dt + \sigma_Y d\hat{B}_{Y,t} + \underbrace{\omega_t dB_{\omega,t}}_{\text{idiosyncratic}},$$

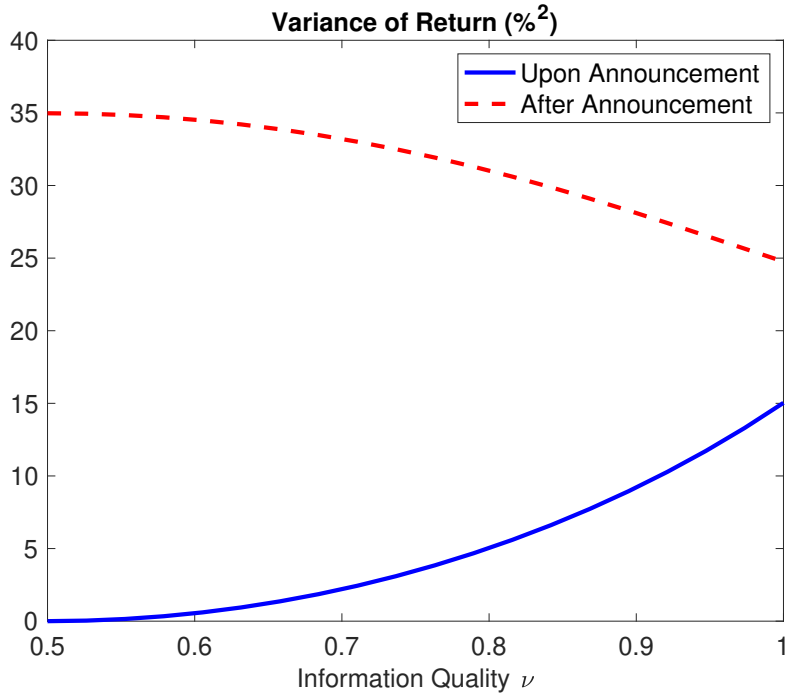
- $\bar{\theta}$: steady-state level of θ_t; ξ: leverage
- Innovations in consumption: $d\hat{B}_{Y,t} = \frac{1}{\sigma_Y}\left(\frac{dY}{Y} - \hat{\theta}_t dt\right)$
- Stochastic vol of idiosyncratic shock in dividend ω_t
  - independent to innovations in consumption $\rightarrow$ not priced

Policy Functions

Implication 1: high informativeness

$\Rightarrow$ high variance of A-day return, low variance in the future

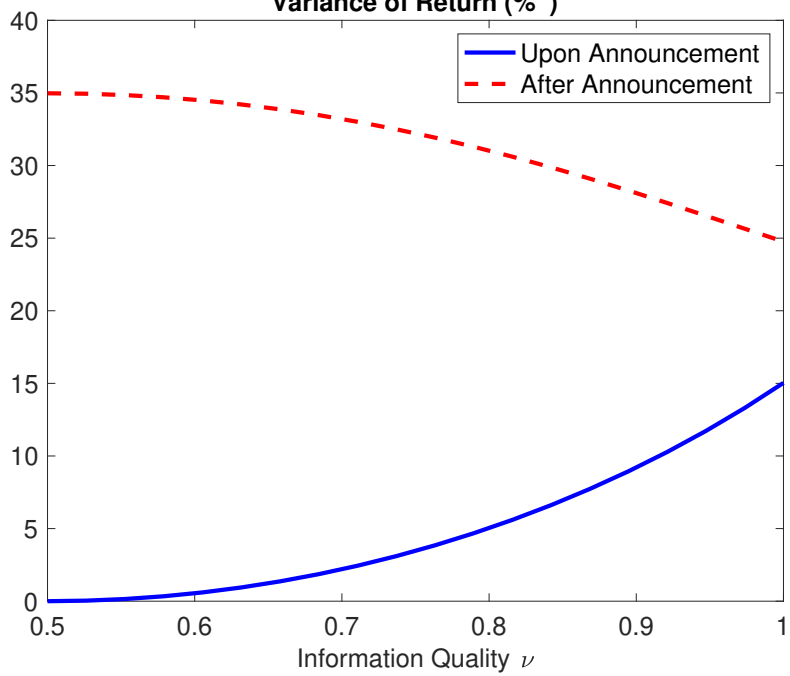
- $\text{Var}\left[\theta_T\right] = \underbrace{\text{Var}\left[\mathbb{E}\left(\theta_T|s_t\right)\right]}_{\text{past vol upon Ann}} + \underbrace{\mathbb{E}\left[\text{Var}\left(\theta_T|s_t\right)\right]}_{\text{future vol after Ann}}$

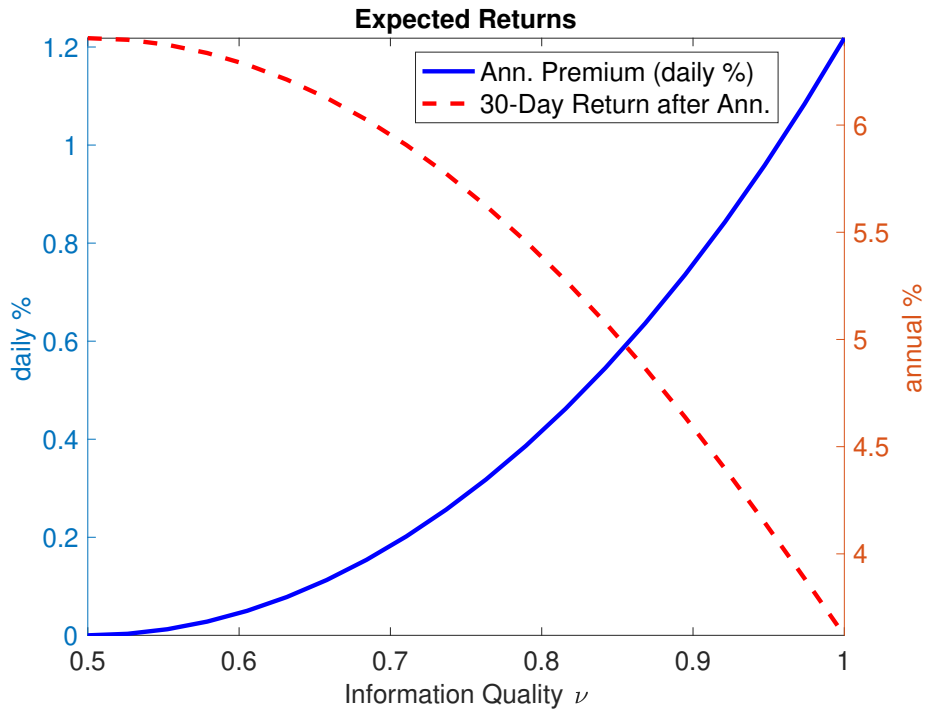


Policy Functions

Implication 2: under strong GRS, high informativeness
$\Rightarrow$ high expected A-day return, low expected return in the future

- Total Return = A-day Return + Expected return after ann.





- *Negative* corr b/w past variance and future expected return

Quantitative Results

Quantitative Results

- Calibration:
  - standard long-run risk parameters
  - FOMC: 8 announcements per year

		Data	Model
$\mathbb{E}[R_A]$	A-day average return	26 bps	29 bps
$\mathbb{E}[R_N]$	NA-day average return	2 bps	1 bps
$AC[RV]$	Autocorrelation of RV	0.65	0.79

- Testing two implications in the data, replicates tests quantitatively in the model

Measuring Informativeness

- Ex post: use A-day implied variance (IV) reduction $\Delta IV_t = VIX_{t-1}^2 - VIX_t^2$ to measure informativeness
  - reflect mkt expected variance on announcement day (A-day)
- Ex ante: use term structure of IV to measure informativeness:

$$IV(9) = Info + 8 \times InfoN,$$
$$IV(30) = Info + 29 \times InfoN.$$

  - *Info*: implied variance on A-day, reflects info content of A-day
  - *InfoN*: implied variance on non-announcement day

Predicting IV Reduction and Returns on FOMC days

- High informativeness $\Rightarrow$ high variance and return on A-days
- Predicting announcement-day returns and IV reduction using informativeness:

$$R_t^{FOMC} = \alpha + \beta \times Info_{t-1} + \epsilon_t$$
$$\Delta IV_t = \alpha + \beta \times Info_{t-1} + \epsilon_t$$

		R_t^{FOMC}	ΔIV_t
$Info_{t-1}$	Data	65.04	6.32
		(4.70)	(3.25)
$R^2(\%)$		15.44	22.20
ν_t	Model	22.22	3.98

Quantitative Results

Informativeness and future realized variance

- Higher informativeness $\Rightarrow$ lower realized variance in the future
- Regress realized variance in the future on IV reductions:

$$RV_{t,t+h} = \alpha + \beta_1 \Delta IV_t + \beta_2 RV_{t-2,t-1} + \epsilon_{t,t+h}$$

# days		1	2	3	4	5	30	60
$RV_{t,t+h}$	Data	-0.12	-0.08	-0.05	-0.05	-0.05	-0.07	-0.04
		(-3.83)	(-3.43)	(-2.41)	(-2.57)	(-2.70)	(-4.15)	(-2.54)
$R^2(\%)$		65.30	58.80	44.94	43.63	43.70	33.16	23.61
$RV_{t,t+h}$	Model	-0.03	-0.03	-0.03	-0.03	-0.03	-0.03	-0.04

Informativeness and Expected Returns

- Higher informativeness $\Rightarrow$ lower returns in the future
- Predicting returns in the future by IV reductions:

$$R_{t,t+h} - r_f = \alpha + \beta_1 \Delta IV_t + \beta_2 RV_{t-2,t-1} + \epsilon_{t,t+h}$$

# days		1	2	3	4	5	30	60
$R_{t,t+h} - r_t$	Data	-2.55	-2.02	-1.08	-1.26	-0.61	-0.19	-0.30
		(-1.03)	(-1.62)	(-1.92)	(-2.08)	(-1.61)	(-1.25)	(-2.03)
$R^2(\%)$		4.55	3.83	3.13	7.83	1.66	1.09	1.73
$R_{t,t+h} - r_t$	Model	-0.57	-0.49	-0.35	-0.26	-0.32	-0.16	-0.24

Quantitative Results: Jumps

Informativeness in jump months and future expected returns

- Informational days: S&P 500 return $> 2.5\%$ or $< -2.5\%$ with news (Baker, Bloom, Davis, and Sammon (2021))
- Regress monthly returns on past month's realized variance:

$$R_{t,t+30} - r_f = \alpha + \beta RV_{t-30,t} + \epsilon_{t,t+30}$$

		Full Sample	Informational Month	The Rest
$R_{t,t+30} - r_f$	Data	-0.16	-0.22	-0.08
		(-2.11)	(-3.50)	(-0.29)
$R^2(\%)$		1.48	4.31	0.03
$R_{t,t+30} - r_f$	Model	-0.05	-0.07	0.12

Quantitative Results: Jumps

Informativeness on jump days and future realized variance

- Higher informativeness $\Rightarrow$ lower realized variance in the future
- Regress realized variance in the future on IV reduction on informational days:

$$RV_{t,t+h} = \alpha + \beta_1 \Delta IV_t + \beta_2 RV_{t-2,t-1} + \epsilon_{t,t+h}$$

# days	1	2	3	4	5	30	60
$RV_{t,t+h}$	-0.07	-0.06	-0.05	-0.04	-0.04	-0.03	-0.02
	(-6.35)	(-6.02)	(-5.49)	(-4.02)	(-4.31)	(-5.92)	(-5.01)
$R^2(\%)$	41.19	39.45	35.35	34.99	38.26	35.05	29.21

Quantitative Results: Jumps

Informativeness on jump days and expected returns

- Higher informativeness $\Rightarrow$ lower returns in the future
- Predicting returns in the future by IV reduction on info days:

$$R_{t,t+h} - r_f = \alpha + \beta_1 \Delta IV_t + \beta_2 RV_{t-2,t-1} + \epsilon_{t,t+h}$$

# days	1	2	3	4	5	30	60
$R_{t,t+h} - r_f$	-1.35	-0.86	-0.49	-0.58	-0.56	-0.10	-0.00
	(-3.96)	(-4.35)	(-2.20)	(-4.25)	(-5.49)	(-1.87)	(-0.08)
$R^2(\%)$	6.60	4.86	2.77	5.73	8.51	3.22	5.82

Variance Risk Premium (VRP) Return Predictability

- VRP return predictability (Bollerslev, Tauchen, Zhou, 2009)
  - without assuming high-frequency variations in consumption vol

$$R_{t,t+h} - r_f = \alpha + \beta \underbrace{\left[IV_{t,t+30} - RV_{t-30,t}\right]}_{VRP_t} + \epsilon_{t,t+h}$$

# days		1	30	60	90	120	150	180
VRP_t	Data	30.21	4.14	5.64	4.27	5.71	3.6	2.93
		(2.68)	(1.44)	(3.42)	(2.83)	(3.05)	(2.68)	(2.35)
$R^2(\%)$		7.58	0.72	2.55	2.11	4.36	2.32	1.67
VRP_t	Model	12.02	1.77	1.06	0.65	0.51	0.43	0.38

- VRP capture the informativeness of announcements arrive at t

Conclusion

- Traditional theory: *positive* relationship between past realized vol and future expected returns
  - important for risk premium, but only at longer horizons
- Information-driven volatility
  - $\Rightarrow$ negative relationship between past RV and expected returns
  - quantitatively more important at higher frequencies
- Important to distinguish the two
  - more empirical work needed

Asset Pricing Moments

Panel A: Aggregate market moments			
$\mathbb{E}[R] - r$	Equity premium	7.46%	5.69%
Std$[R]$	Vol of stock mkt return	18.55%	12.03%
$\mathbb{E}[r]$	Avg risk-free rate	0.26%	0.42%
Std$[r]$	Vol of risk-free rate	1.08%	0.92%
$\mathbb{E}[dY/Y]$	Cons. growth rate	1.74%	1.33%
Std$[dY/Y]$	Vol of cons. growth	2.72%	3.36%
AC$[dY/Y]$	AC(1) of cons. growth	0.38	0.36
$\mathbb{E}[dD/D]$	Dividend growth rate	1.55%	1.24%
Std$[dD/D]$	Vol of div. growth	10.66%	9.12%
AC$[dD/D]$	AC(1) of div. growth	0.17	0.35
Corr$(dY/Y, dD/D)$	Corr cons. and div.	0.43	0.64
AC$[RV]$	AC(1) of RV	0.65	0.79
Panel B: Announcement moments			
$\mathbb{E}[R^A]$	A-day avg return	26 bps	29 bps
$\mathbb{E}[R^N]$	NA-day avg return	2 bps	1 bps
$\mathbb{E}[\Delta IV_T]$	Av. IV reduction	2.14	4.18
Std$[\Delta IV_T]$	Std. of IV reduction	8.86	4.87

Implied Variance Reduction

	Q5	Q25	Q50	Q75	Q95
Data	−5.54	−0.26	1.14	3.88	10.00
Model	−0.29	0.24	1.82	7.07	14.63

Quantiles of the 30-day implied variance drop on announcement days. Data: 1994.09–2019.12. Units: monthly percentage squared.

Quantitative Results: Earnings Announcement

- Test whether announcement-day realized variance could predict future return and variance

$$
\begin{aligned}
R_{i,t+h} \quad = \quad & \alpha_{1,h} + \alpha_{2,h} \cdot 1_{EA} + \beta_{1,h} RV_{i,t} + \beta_{2,h}(1_{EA} \times RV_{i,t}) \\
& + \gamma_h RV_{i,t-1} + \delta_{1,h} R_{i,t} + \delta_{2,h}(1_{EA} \times R_{i,t}) + \alpha_{3,i} + \alpha_{4,t} + \epsilon
\end{aligned}
$$

	1	2	3	4	5	30	60
Panel A: Return							
$\beta_{2,h}$	-0.188	-0.105	-0.060	-0.040	-0.037	-0.015	-0.017
	[-6.18]	[-5.40]	[-4.14]	[-3.28]	[-3.82]	[-3.50]	[-5.29]
R^2	0.082	0.092	0.100	0.106	0.111	0.147	0.147
Panel B: RV							
$\beta_{2,h}$	-0.160	-0.134	-0.122	-0.115	-0.110	-0.077	-0.061
	[-39.08]	[-46.78]	[-50.01]	[-52.54]	[-52.60]	[-55.23]	[-52.21]
R^2	0.152	0.216	0.257	0.286	0.308	0.418	0.458