Idiosyncratic Jump Risk Matters: Evidence from Equity Returns and Options

Jean-François BÉGIN (Simon Fraser University)
Christian DORION (HEC Montreal)
Geneviève GAUTHIER (HEC Montreal)

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Idiosyncratic Risk Should not be Priced

- The pricing of idiosyncratic risk is a contentious matter

- In a CAPM world, obtaining the equity risk premium (ERP) on **a single stock** is straightforward
  - Given the market's ERP and the stock's β, you're done.

$$\mathrm{E}^{\mathbb{P}}\left[r_{S,t+1} - r_{f,t+1}\right] = \mathrm{E}^{\mathbb{P}}\left[\beta_S^{\text{CAPM}}(r_{M,t+1} - r_{f,t+1}) + \varepsilon_{t+1}\right] = \beta_S^{\text{CAPM}}\,\mathrm{E}^{\mathbb{P}}\left[r_{M,t+1} - r_{f,t+1}\right]$$

  - Alternate **factor models**: additional systematic factors, but idiosyncratic risk should not be priced.

- Idiosyncratic $\equiv$ Diversifiable

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- Idiosyncratic ≡ Diversifiable… But is it diversified?

Idiosyncratic Risk Could be Priced

- In theory, under-diversification could lead to a **positive risk premium** for **undiversified** idiosyncratic risk, e.g. Merton (1987, JF):

$$\mathrm{E}^{\mathbb{P}}\left[r_S - r_f\right] = \nu \,\mathrm{Var}^{\mathbb{P}}(r_M)\beta_S^{\text{CAPM}} + \nu\,\omega_S\left(\frac{1}{q_S} - 1\right)\sigma_S^2$$

- Aggregating across stocks:

$$\mathrm{E}^{\mathbb{P}}\left[r_M - r_f\right] = \nu \,\mathrm{Var}^{\mathbb{P}}(r_M) + \nu \sum_{S \in \mathbb{S}} \omega_S \widehat{\lambda}_S \sigma_S^2$$

with $\widehat{\lambda}_S = \omega_S\left(\frac{1}{q_S} - 1\right)$

+ Mitton and Vorkink (2007, RFS) argue that preference for skewness could lead to under-diversification in equilibrium.
+ Kacperczyk, Sialm and Zheng (2005, JF) provide evidence that mutual fund managers may optimally deviate from a well-diversified portfolio.
+ Lines (2016) "Do Institutional Incentives Distort Asset Prices?" → yes

Idiosyncratic Risk Appears to be Priced... Or Not

- Empirically,
  - Some studies find idiosyncratic risk to carry a **negative** risk premium (e.g. Ang, Hodrick, Xing, and Zhang (2006, JF, 2009, JFE))
  - Some studies find idiosyncratic risk to carry a **positive** risk premium (e.g. Goyal and Santa Clara (2003, JF), Fu (2009, JFE))
  - Some studies claim it **does not carry a premium** (e.g. Bali, Cakici, Yan, and Zhang (2005,JF), Bali, Cakici (2008,JFQA))

- None of these studies make a distinction between **diffusive** and **jump risk**, neither systematic nor idiosyncratic
  - Idiosyncratic diffusive risk should not be too hard to diversify…
  - Is idiosyncratic jump risk as easy to diversify?
  - Skewness is not a subadditive measure…

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with $\boxed{\widehat{\lambda}_S = \omega_S \left(\frac{1}{q_S} - 1\right) \ll 1.}$

- In all likelihood, market frictions are not severe enough for the **total idiosyncratic risk**, σ_S, to be a valid proxy of **undiversified idiosyncratic risk**, $\widehat{\lambda}_S \sigma_S$.

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- Note that the risk premium in excess of that on the market is:

$$\mathrm{E}^{\mathbb{P}}\left[r_S - r_M\right] = \nu(\beta_S^{\text{CAPM}}\boxed{-1})\,\mathrm{Var}^{\mathbb{P}}(r_M) + \nu\left(\widehat{\lambda}_S\sigma_S^2\boxed{-\sum_{S'\in\mathbb{S}}\omega_{S'}\widehat{\lambda}_{S'}\sigma_{S'}^2}\right).$$

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  - Is idiosyncratic jump risk as easy to diversify?
  - **Total idiosyncratic risk** = Diversified Idio Risk + **Undiversified Idio Risk**
    - Severe errors-in-variables issues (Ruan, Sun, and Xu (2016))

Main Contributions

- ✦ We develop an option-valuation model allowing to disentangle 4 components of a stock's ERP: **systematic** / **idiosyncratic** × **normal** / **jump**
  - + We exploit the richness of stock option data to extract the expected risk premium associated with each risk factor, thereby avoiding the exclusive use of noisy realizations of historical equity returns.

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- Model-implied contribution to the total ERP on an average stock
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Easily diversifiable idiosyncratic diffusive risk is not priced.

Idiosyncratic jump risk is!

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- Commonality in idiosyncratic **jump risk (50%)** is much stronger than that in **total (36%)** idiosyncratic risk (35% in Herskovic, Kelly, Lustig, and Van Nieuwerburgh, 2016, JFE)

The Model in a Nutshell

- In our model, stocks are exposed to 2 systematic risk factors: Gaussian and Jump
  - The market model is based on Ornthanalai (2014, JFE). It is a GARCH model that admits a continuous time limit of the form:

$$
\begin{aligned}
d\log M_t &= \mu(V_t,\lambda_t)dt + \sqrt{V_t}dW_t + dY_t \\
dV_t &= a(V_t)dt + b(V_t)dW_t \\
d\lambda_t &= c(V_t,\lambda_t)dt + d(V_t)dW_t, \quad Y_t = \sum_{n=1}^{N_t} J_n,\ J_n \sim \mathrm{NIG}(\alpha,\delta,\gamma)
\end{aligned}
$$

- We have a model with 4 sources of risk, two of which are jumps:

$$
\begin{aligned}
\log\left(\frac{M_{t+1}}{M_t}\right) &\equiv \mu_{M,t+1} - \xi^{\mathbb{P}}_{M,t+1} + z_{M,t+1} + y_{M,t+1}, \\
\log\left(\frac{S_{t+1}}{S_t}\right) &\equiv \boxed{\mu_{S,t+1}} - \xi^{\mathbb{P}}_{S,t+1} + \beta_{S,z} z_{M,t+1} + \beta_{S,y} y_{M,t+1} + z_{S,t+1} + y_{S,t+1},
\end{aligned}
$$

The Model… In Too Much Details

$$\log\left(\frac{M_{t+1}}{M_t}\right) \equiv \mu_{M,t+1} - \xi^{\mathbb{P}}_{M,t+1} + z_{M,t+1} + y_{M,t+1},$$

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$$z_{u,t+1} \sim \mathcal{N}\left(0; h_{u,z,t+1}\right), \quad y_{u,t+1} \sim \mathrm{NIG}\left(\alpha_u; \delta_u; h_{u,y,t+1}\right), \quad u \in \{M, S\}$$

where $\xi^{\mathbb{P}}_{\cdot,t+1}$ are convexity corrections such that $\mathrm{E}^{\mathbb{P}}_t[M_{t+1}] = M_t \exp(\mu_{M,t+1})$ and $\mathrm{E}^{\mathbb{P}}_t[S_{t+1}] = S_t \exp(\mu_{S,t+1})$

Finally,

$$h_{M,z,t+1} = w_{M,z} + b_{M,z} h_{M,z,t} + \frac{a_{M,z}}{h_{M,z,t}}\left(z_{M,t} - c_{M,z} h_{M,z,t}\right)^2.$$

$$h_{M,y,t+1} = w_{M,y} + b_{M,y} h_{M,y,t} + \frac{a_{M,y}}{h_{M,z,t}}\left(z_{M,t} - c_{M,y} h_{M,z,t}\right)^2.$$

$$\begin{aligned} h_{S,z,t+1} &= \kappa_{S,z} h_{M,z,t+1} \\ &\quad + b_{S,z}\left(h_{S,z,t} - \kappa_{S,z} h_{M,z,t}\right) + \frac{a_{S,z}}{h_{S,z,t}}\left(z^2_{S,t} - h_{S,z,t} - 2c_{S,z} h_{S,z,t} z_{S,t}\right). \end{aligned}$$

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Herskovic, Kelly, Lustig, and Van Nieuwerburgh (2016)

Bartram, Brown, and Stulz (2016)

The Model in a Nutshell

- The GARCH-like framework allows us to derive a simpler filter
  - Given that there are 2 shocks associated with each return, this is not strictly speaking a GARCH model
  - Yet, the filter is much faster and numerically stable than its full SV counterpart
- Sequential importance resampling (SIR) <u>without</u> the well-known sample impoverishment issue
- We have derived an extension of the APF suggested in Johannes, Polson, and Stroud (2009). In a simulation study, our filter proved to be as accurate while being much more tractable.
- In the estimation NIG jumps are much better behaved than compound Poisson jumps

Idio. ERP: The Expected Excess Return on a Stock

- The **equity risk premium on a stock**, $\mu_{S,t+1} - r_{t+1}$, can be decomposed in four risk premiums :

$$\boxed{\mu_{S,t+1} - r_{t+1}}$$

$$= \underbrace{\beta_{S,z}\lambda_M h_{M,z,t+1} + \gamma_{M,S}(\beta_{S,y}) h_{M,y,t+1}}_{\text{systematic}} + \underbrace{\lambda_{S,t+1} h_{S,z,t+1} + \gamma_{S,t+1} h_{S,y,t+1}}_{\text{idiosyncratic}}$$

where λ_M, $\gamma_{M,S}(\beta_{S,y})$, $\lambda_{S,t+1}$ and $\gamma_{S,t+1}$ are parameters of the pricing kernel…

- Predictable processes $\lambda_{S,t+1}$ and $\gamma_{S,t+1}$ are essentially
  + A constant (λ_S or γ_S) – In Merton (1987, JF) $\propto \nu\, \omega_S \left(\frac{1}{q_S} - 1\right)$.
  + Time variation determined by the clearing conditions (also inspired from Merton (1987, JF))

$$\mathrm{E}^{\mathbb{P}}\left[r_S - r_M\right] = \nu(\beta_S^{\text{CAPM}} - 1)\,\mathrm{Var}^{\mathbb{P}}(r_M) + \boxed{\nu\left(\widehat{\lambda}_S \sigma_S^2 - \sum_{S' \in \mathbb{S}} \omega_{S'} \widehat{\lambda}_{S'} \sigma_{S'}^2\right)}.$$

Methodological Contribution

- First to derive & estimate a model **(i)** linking **returns** and **option prices** and **(ii)** decomposing the equity risk premium along these **four important dimensions**:

$$\mathrm{E}_t^{\mathbb{P}}\left[r_{S,t+1} - r_{f,t+1}\right] = \beta_{\text{diff}}\,\textbf{Syst. Diffusive RP} + \beta_{\text{jump}}\,\textbf{Syst. Jump RP}$$

$$+\,\textbf{Idio. Diffusive RP} + \textbf{Idio. Jump RP}$$

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+ Inspired by Christoffersen, Fournier and Jacobs (201?, RFS), Elkhamhi and Ornthanalai (2010), Babaoğlu (2016)
+ In our setup, the "CAPM" beta depends on the proportion of variance due to jumps:

$$\beta_{S,t+1}^{\text{CAPM}} \simeq \frac{\mathrm{Cov}_t^{\mathbb{P}}\left(\beta_{S,z} z_{M,t+1} + \beta_{S,y} y_{M,t+1},\, z_{M,t+1} + y_{M,t+1}\right)}{\mathrm{Var}_t^{\mathbb{P}}\left(z_{M,t+1} + y_{M,t+1}\right)} = \frac{\beta_{S,z} h_{M,z,t+1} + \beta_{S,y} \frac{\alpha_M^2}{(\alpha_M^2 - \delta_M^2)^{3/2}} h_{M,y,t+1}}{h_{M,z,t+1} + \frac{\alpha_M^2}{(\alpha_M^2 - \delta_M^2)^{3/2}} h_{M,y,t+1}}$$

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+ Cross-sectional implications of higher co-moments or (syst.) crash risk: Harvey and Siddique (2000, JF), Conrad, Dittmar, and Ghysels (2013, JF), Kelly and Jiang (2014, RFS), Bollerselv, Todorov, and Zhengzi Li (2016, JFE), Kelly, Lustig, and Van Nieuwerburgh (2016, AER), Babaoglu (2015), Schneider, Wagner, and Zechner (2016)
+ Gourier (2016): Has idiosyncratic jumps, but does not study their pricing relative to diffusive risk.

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- The use of option prices and returns allows us to capture the wedge between risk-neutral and physical measures, and therefore **obtain a robust decomposition of the equity risk premium at the stock level**
  + Options and returns over 20 years, for 260 stocks.
  + Options are crucial to alleviate the Peso problem associated with the pricing of jumps
    - The price of deep OTM options reflects the (Q) probability of jumps occurring
  + To our knowledge, the most extensive option-pricing exercise in the literature.

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Results are robust to using only shortest-maturity options

Empirical Contribution

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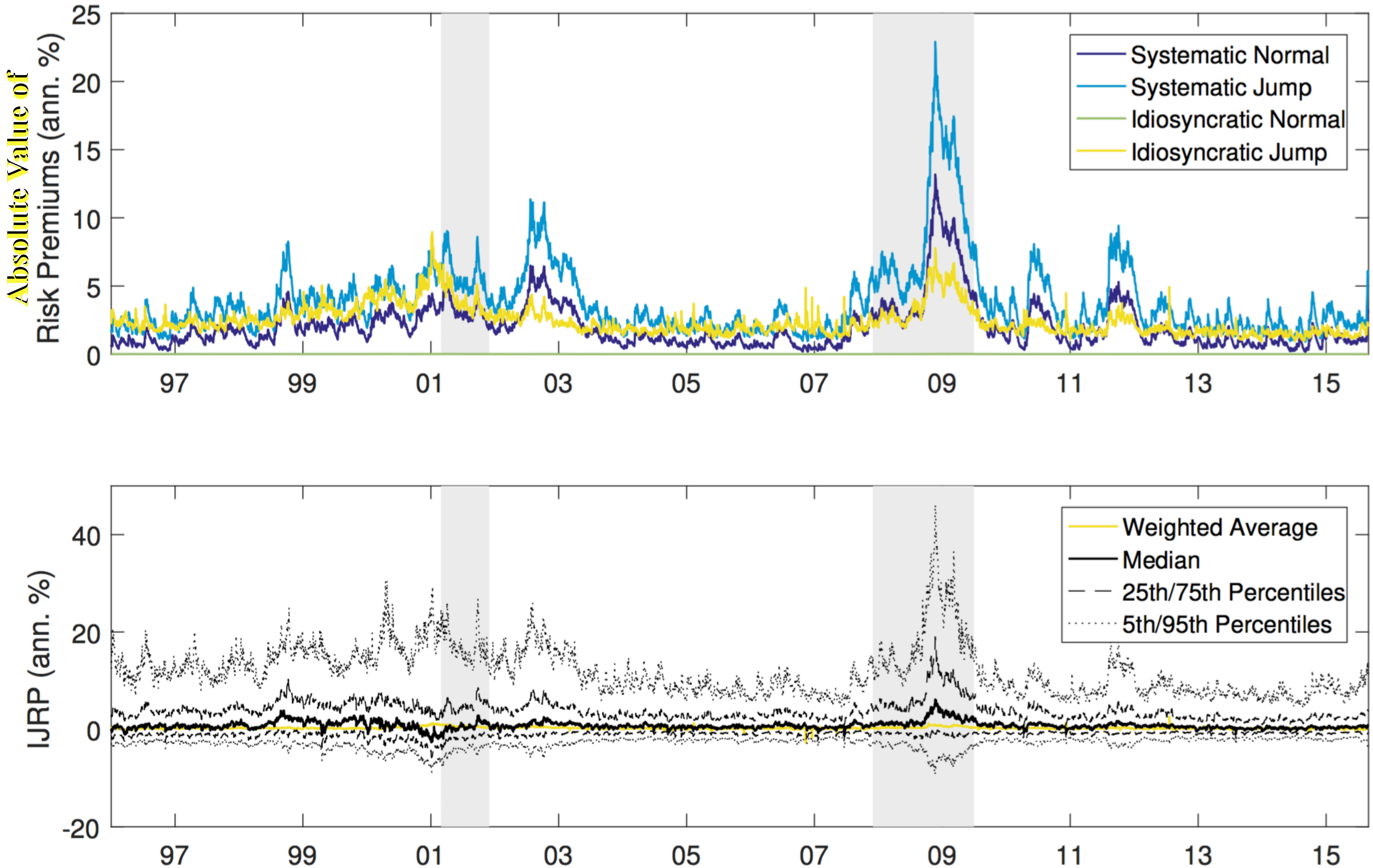
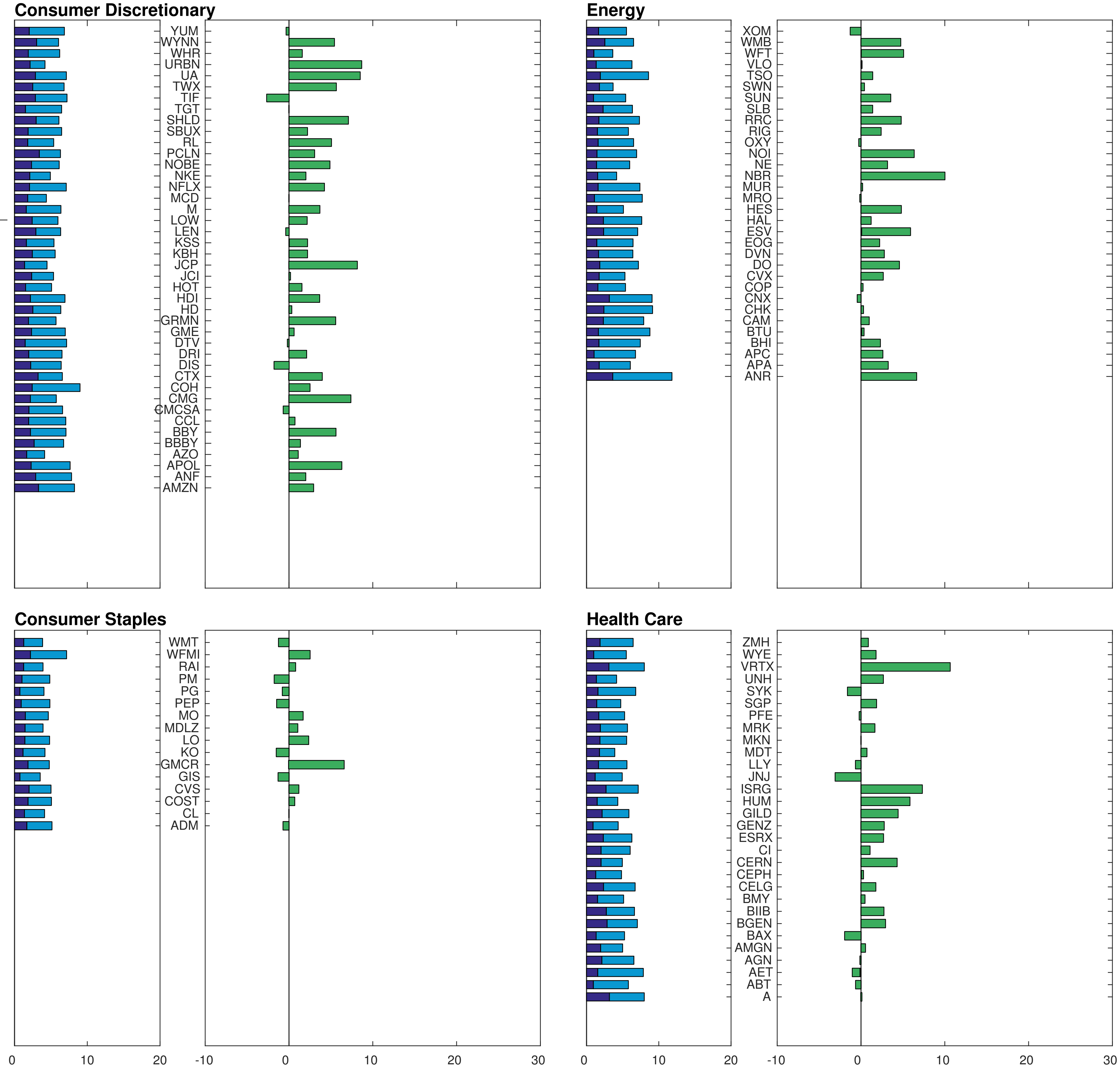
Risk Premiums:
Time-Series of Cap-Weighted Averages



Equity Risk Premium Decomposition

- ✦ Cross-section of time-series averages
- ✦ At a given point in time, the cross-sectional average is zero by construction…
- ✦ Jump intensity (just like variance) exhibits very large positive skewness



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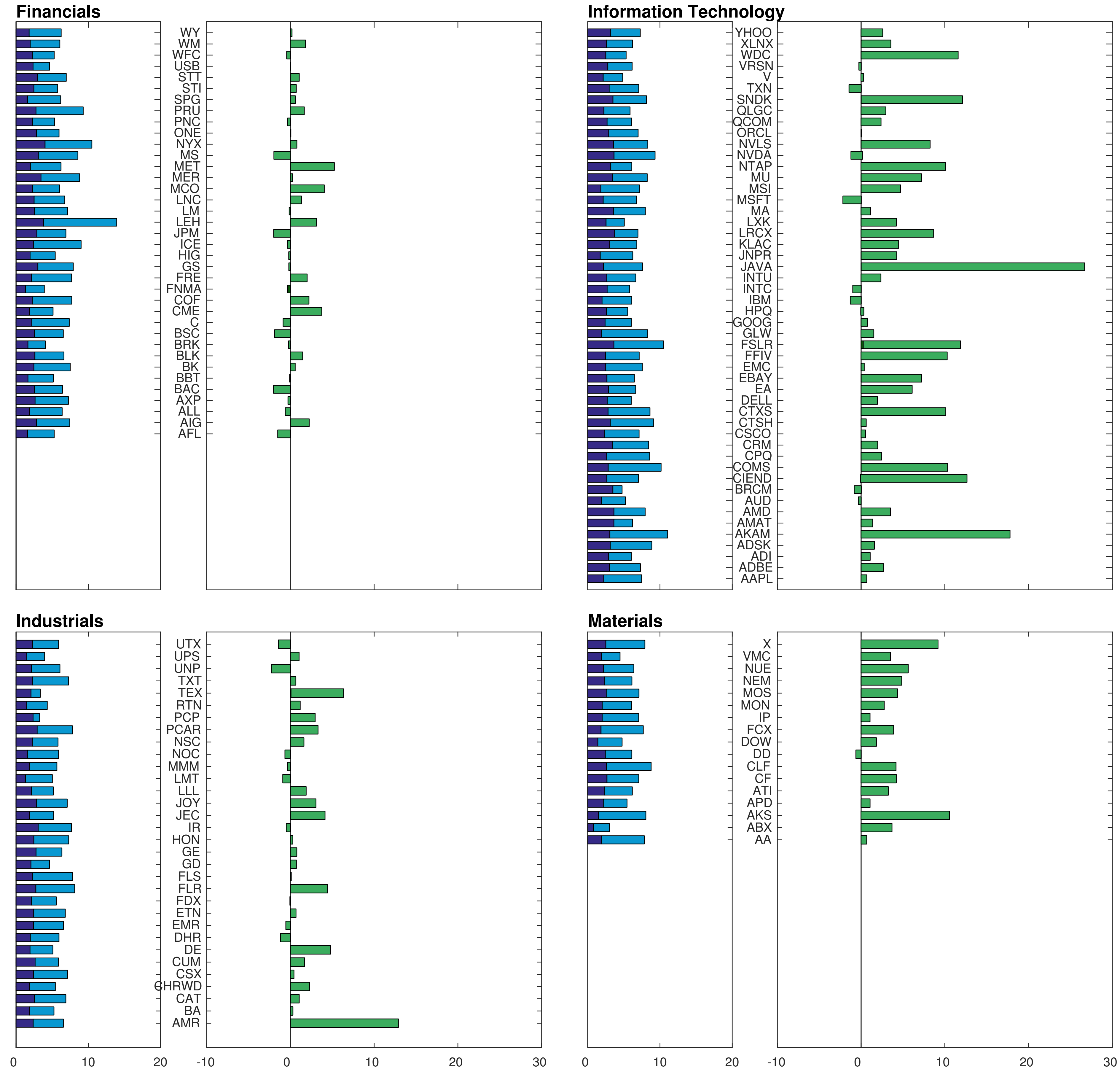

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Is the model-implied IJRP actually ***reflected in returns***
or does it just make up for the misspecification of the model?

Portfolios Based on the Idiosyncratic Jump Risk Premium

$$r_t^{P5-P1} = \alpha + \beta_{\text{MKT}}\text{MKT}_t + \beta_{\text{SMB}}\text{SMB}_t + \beta_{\text{HML}}\text{HML}_t + \beta_{\text{RMW}}\text{RMW}_t + \beta_{\text{CMA}}\text{CMA}_t + \beta_{\text{MOM}}\text{MOM}_t + \beta_{\Delta\text{VIX}}\Delta\text{VIX}_t + \epsilon_t,$$

$$\text{IDRP} = \text{E}_t^{\mathbb{P}}\left[\exp\left\{\lambda_S h_{S,t+1} - \xi^{\mathbb{P}}_{z_{S,t+1}} + z_{S,t+1}\right\}\right] = e^{\lambda_S h_{S,t+1}} \qquad \text{IJRP} = \text{E}_t^{\mathbb{P}}\left[\exp\left\{\gamma_S h_{S,t+1} - \xi^{\mathbb{P}}_{y_{S,t+1}} + y_{S,t+1}\right\}\right] = e^{\gamma_S h_{S,t+1}}$$

	Idiosyncratic Diffusive Risk Premium					Idiosyncratic Jump Risk Premium				
	FF3	FF5	MOM	AHXZ	All	FF3	FF5	MOM	AHXZ	All
Cst $\times \frac{100}{\Delta t}$	0.94	3.69	1.73	0.73	3.86	8.60**	15.14**	11.77**	8.39**	17.00**
	(0.38)	(1.51)	(0.69)	(0.30)	(1.57)	(2.31)	(4.16)	(3.29)	(2.27)	(4.76)
MKT	0.12**	0.04**	0.10**	0.14**	0.04*	0.47**	0.29**	0.39**	0.50**	0.21**
	(6.95)	(2.16)	(5.69)	(6.07)	(1.65)	(15.32)	(13.75)	(15.59)	(10.64)	(6.48)
SMB	0.10**	0.05**	0.10**	0.09**	0.05**	0.29**	0.18**	0.32**	0.29**	0.21**
	(3.68)	(2.06)	(3.83)	(3.58)	(2.22)	(7.77)	(4.84)	(9.02)	(7.71)	(5.94)
HML	-0.55**	-0.36**	-0.59**	-0.55**	-0.39**	-0.12	0.33**	-0.28**	-0.11	0.17**
	(-17.23)	(-11.93)	(-17.27)	(-17.41)	(-11.38)	(-1.49)	(6.16)	(-4.36)	(-1.44)	(3.44)
RMW		-0.23**			-0.22**		-0.53**			-0.49**
		(-5.51)			(-5.23)		(-8.77)			(-8.78)
CMA		-0.47**			-0.45**		-1.14**			-1.01**
		(-7.95)			(-7.66)		(-13.34)			(-12.79)
MOM			-0.09**		-0.03			-0.35**		-0.23**
			(-3.58)		(-1.57)			(-7.56)		(-5.92)
DVIX				0.02*	0.00				0.02	-0.04*
				(1.73)	(0.27)				(0.90)	(-1.82)
Adj. R^2	0.22	0.28	0.23	0.23	0.28	0.24	0.38	0.30	0.24	0.40

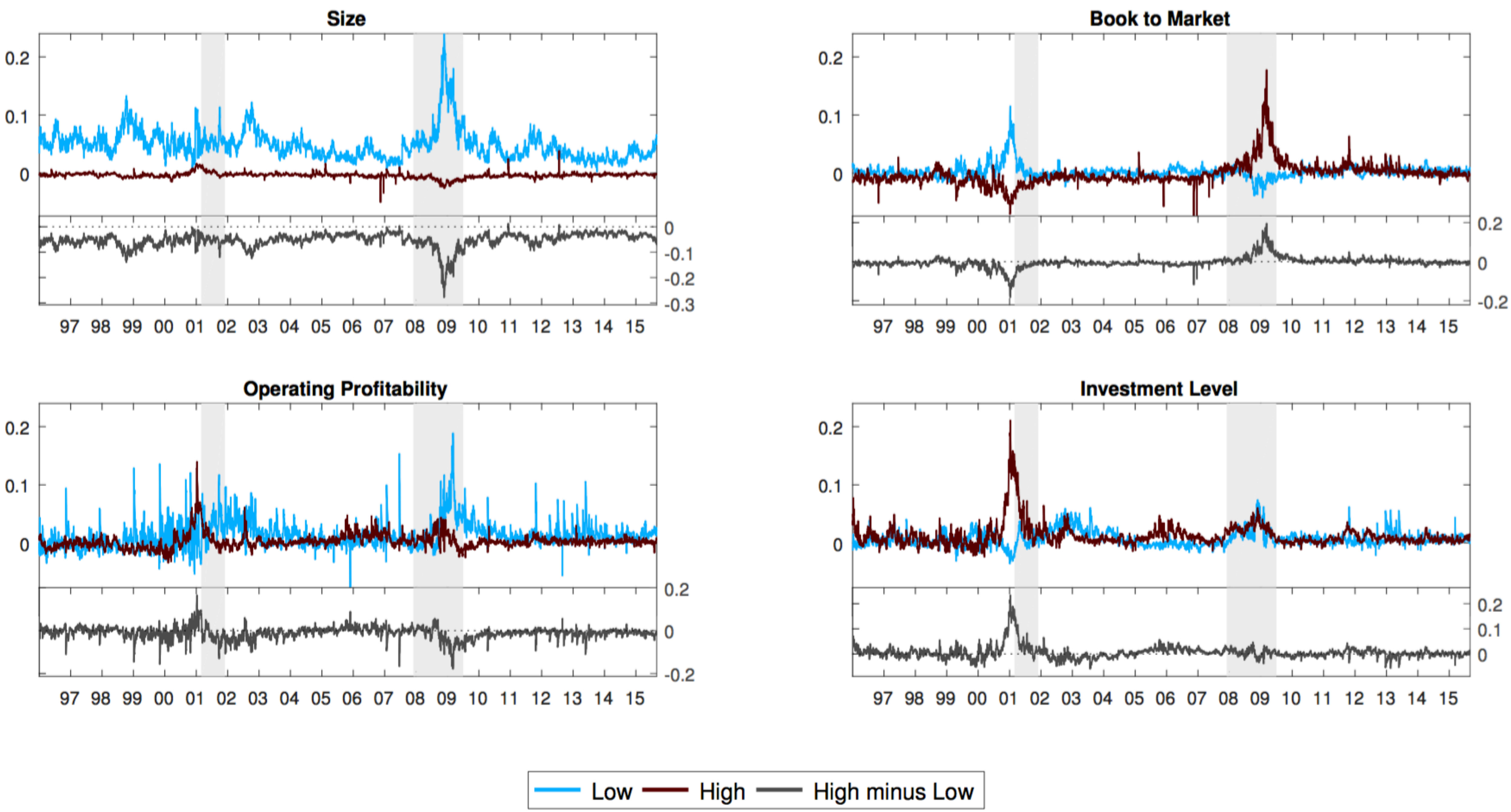
**: 5% significance *: 10% significance.

Portfolios Based on the Idiosyncratic Jump Risk Premium

	Idiosyncratic Jump Risk Premium				
	P1	P2	P3	P4	P5
Market beta	0.96	0.98	1.08	1.12	1.23
	[0.12]	[0.11]	[0.11]	[0.13]	[0.23]
log(ME)	25.30	25.03	24.72	24.43	24.07
	[0.32]	[0.35]	[0.46]	[0.48]	[0.59]
BE/ME	1.57	1.50	1.54	1.43	1.64
	[0.54]	[0.53]	[0.94]	[1.05]	[1.77]
OP (%)	5.96	5.67	5.71	5.67	5.37
	[1.39]	[1.63]	[1.47]	[1.55]	[1.92]
Investment (%)	16.27	16.12	19.43	21.86	29.47
	[22.14]	[17.68]	[25.46]	[29.31]	[55.54]
Return [-12,-2] (%)	13.67	14.25	16.52	18.55	23.02
	[18.40]	[18.35]	[22.88]	[27.10]	[38.96]
Volatility beta (%)	-0.28	0.56	0.95	-0.26	-1.53
	[3.38]	[3.64]	[4.31]	[5.90]	[9.42]

- As we go from P1 to P5, firms have increasing market beta, decreasing market capitalization
- Patterns in the other variables are not as robust: increasing past performance, and appear increasingly aggressive in their investments
- Volatility exposure is inverse U-shaped

Only Size Seems Robust



Double Sorting: First on Characteristic Then on Idiosyncratic Jump Risk Premium

$$r_t^{P5-P1} = \alpha + \beta_{\text{MKT}}\text{MKT}_t + \beta_{\text{SMB}}\text{SMB}_t + \beta_{\text{HML}}\text{HML}_t + \beta_{\text{RMW}}\text{RMW}_t + \beta_{\text{CMA}}\text{CMA}_t + \beta_{\text{MOM}}\text{MOM}_t + \beta_{\Delta\text{VIX}}\Delta\text{VIX}_t + \epsilon_t,$$

	Idiosyncratic Jump Risk Premium				
	Q1	Q2	Q3	Q4	Q5
Market beta	7.14*	8.75**	11.63**	9.98**	11.41**
	(1.91)	(2.38)	(3.05)	(2.38)	(2.19)
log(ME)	11.49**	9.08**	10.51**	18.45**	10.62**
	(2.43)	(2.38)	(3.20)	(5.81)	(3.96)
BE/ME	15.13**	12.26**	11.90**	15.12**	12.54**
	(3.41)	(2.62)	(2.86)	(3.80)	(3.13)
OP (%)	17.02**	10.48**	14.18**	6.99	16.34**
	(3.05)	(2.21)	(2.95)	(1.52)	(3.41)
Investment (%)	11.94**	8.66**	18.11**	20.14**	12.60**
	(2.54)	(2.31)	(4.74)	(4.40)	(2.49)
Return [-12,-2] (%)	10.91**	5.38	13.13**	13.14**	14.59**
	(2.07)	(1.37)	(3.54)	(3.42)	(3.03)
Volatility beta (%)	5.37	10.51**	18.33**	9.63**	19.35**
	(1.05)	(2.51)	(4.80)	(2.57)	(3.89)

**: 5% significance *: 10% significance.

- ✦ These are (35) alphas obtained in each double sort bucket
- ✦ The IJRP remain statistically and economically significant across the board

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IJRP vs Intermediary Asset Pricing

- Marginal investor in option market is typically an intermediary (Bates (2003, JEc) and Garleanu, Pedersen and Poteshman (2009,RFS))
  - + Jump risk vs Gamma hedging?

- Intermediary Capital Ratio (ICR) factor (He, Kelly and Manela (2017, JFE))

Averages from stock by stock regressions

	Ex.Ret
β_{ICR}	0.60
R^2	0.19

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	Ex.Ret	R(SNR)	R(SJR)	R(INR)	R(IJR)
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Averages from stock by stock regressions

	Ex.Ret	R(SNR)	R(SJR)	R(INR)	R(IJR)
β_{ICR}	0.60	0.41	0.04	0.09	0.00
R^2	0.19	0.51	0.22	0.04	0.01

IJRP vs Intermediary Asset Pricing

- ✦ Intermediary Capital Ratio (ICR) factor (He, Kelly and Manela (2017, JFE))

	ICR	All+ICR
Cst $\times \frac{100}{\Delta t}$	13.78**	18.59**
	(3.10)	(4.83)
MKT		0.30**
		(7.60)
SMB		0.15**
		(3.54)
HML		0.25**
		(4.82)
RMW		-0.47**
		(-8.37)
CMA		-1.13**
		(-12.44)
MOM		-0.20**
		(-4.66)
DVIX		-0.04*
		(-1.78)
ICR	0.28**	-0.06**
	(12.99)	(-2.61)
Adj. R^2	0.17	0.45

Note: Period 2000-2015

IJRP vs Intermediary Asset Pricing

- Intermediary Capital Ratio (ICR) factor (He, Kelly and Manela (2017, JFE))

	Q1	Q2	Q3	Q4	Q5
Market beta	6.62*	9.04**	13.94**	14.13**	12.87**
	(1.69)	(2.35)	(3.44)	(3.17)	(2.23)
log(ME)	12.32**	9.18**	9.56**	17.68**	10.51**
	(2.55)	(2.28)	(2.66)	(5.05)	(3.63)
BE/ME	23.70**	13.99**	12.95**	8.86**	9.98**
	(5.02)	(2.86)	(2.95)	(1.97)	(2.14)
OP (%)	18.83**	11.94**	20.92**	17.78**	23.38**
	(3.12)	(2.39)	(4.22)	(3.63)	(4.66)
Investment (%)	18.11**	10.07**	17.97**	24.19**	12.36**
	(3.50)	(2.51)	(4.37)	(5.08)	(2.40)
Return [-12,-2] (%)	11.77**	8.57**	11.63**	14.87**	17.16**
	(2.02)	(2.01)	(2.92)	(3.59)	(3.38)
Volatility beta (%)	7.72	13.96**	12.79**	12.45**	25.05**
	(1.44)	(3.13)	(3.34)	(3.12)	(4.55)
ICR beta (%)	7.13*	13.75**	9.72**	25.55**	8.37
	(1.88)	(3.42)	(2.35)	(5.17)	(1.37)

Note: Period 2001-2015

Empirical Contribution

- Model-implied contribution to the total ERP on an average stock
  - **Systematic diffusive risk premium: 2.3% – 38% of total**
  - **Systematic jump risk premium: 3.9% – 62% of total**
  - **Idiosyncratic diffusive risk premium: 0.0%**
  - **Idiosyncratic jump risk premium (IJRP): ± 2.4% – ± 39% of total**

- Long-short portfolio of stocks sorted based on their **IJRP**
  - Alpha between **8.4% and 17.8%** (depending on the chosen set of factors)
  - Smaller firms and "losers" tend to exhibit higher **IJRP**
  - Patterns based on book to market, operating profitability, investment rates or exposure to aggregate volatility shocks vary through time.
  - Abnormal returns hold even for double-sort portfolios
    - No single one of these other variables appears to be driving our results

Conclusion

Gaussian, and thus easily diversifiable idiosyncratic risk is not priced.

Idiosyncratic jump risk is, and positively so.

Conclusion

Gaussian, and thus easily diversifiable idiosyncratic risk is not priced.

(It accounts for 90.5% of total idiosyncratic variance)

Idiosyncratic jump risk is, and positively so.

(It accounts for 9.5% of total idiosyncratic variance)