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Attilio Meucci

Fully Flexible Views: Theory and Practice

- **Article:**
  "Fully Flexible Views: Theory and Practice"
  The Risk Magazine **- October 2008, p 97-102**
  available at www.symmys.com > Research > Working Papers

- **MATLAB examples:**
  www.symmys.com > Teaching > MATLAB

- **This presentation:**
  www.symmys.com > Teaching > Talks

Attilio Meucci - *Fully Flexible Views: Theory and Practice* - the punch line: scenario analysis

probability = 1 / num scenarios

market distribution

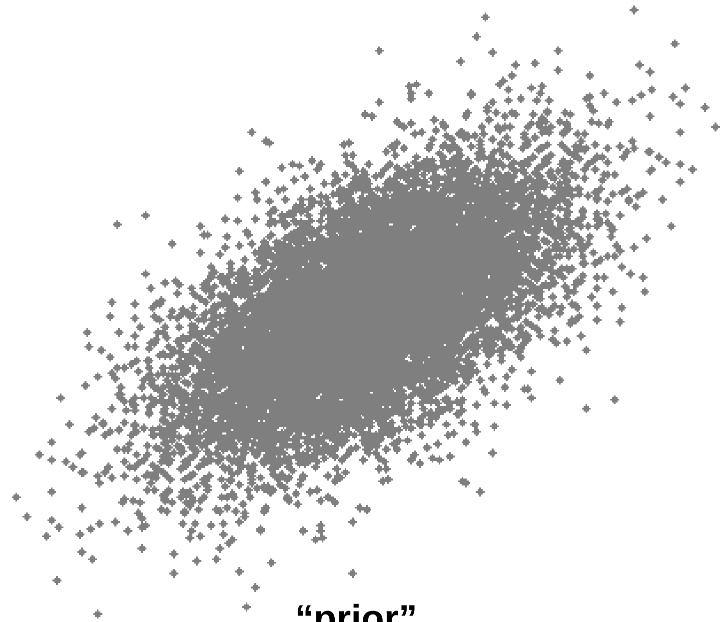
Attilio Meucci - *Fully Flexible Views: Theory and Practice* - the punch line: scenario analysis

probability = 1 / num scenarios

regular market

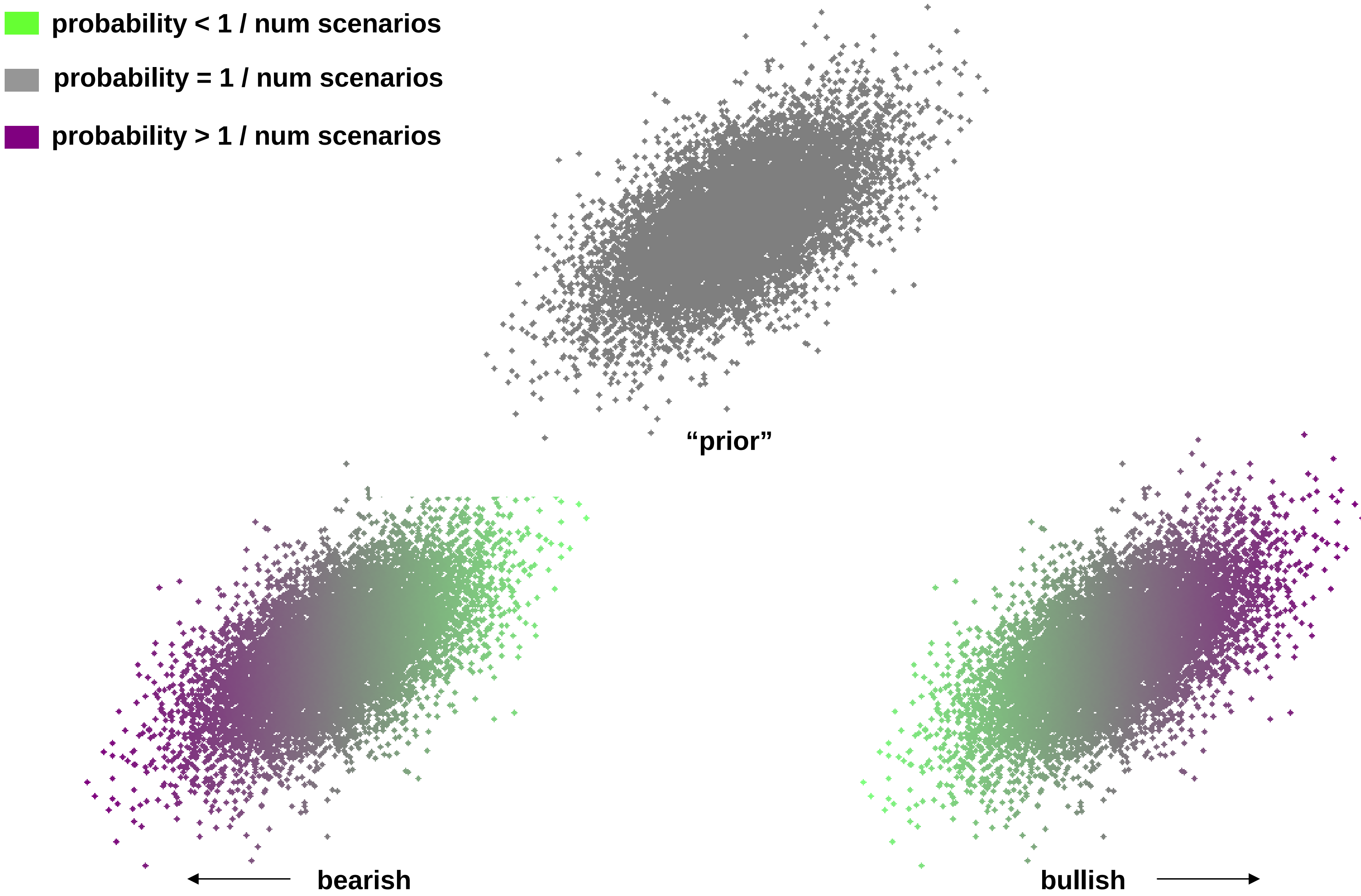
Attilio Meucci - *Fully Flexible Views: Theory and Practice* - the punch line: stress-testing

probability = 1 / num scenarios



“prior”

Attilio Meucci - *Fully Flexible Views: Theory and Practice* - the punch line: Black-Litterman



RELATED LITERATURE

UNIFIED FRAMEWORK: ENTROPY POOLING

ANALYTICAL SOLUTION

FULLY GENERAL IMPLEMENTATION

CASE STUDIES: RANKING ALLOCATION, OPTION TRADING

CONCLUSIONS

REFERENCES

Market distribution

$\mathbf{X} \sim \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$ **returns on asset classes/funds**

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Scenario analysis

$\mathbf{QX} \equiv \mathbf{v}$

Market distribution

$\mathbf{X} \sim \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$ **returns on asset classes/funds**

Scenario analysis

$$\mathbf{Q}\mathbf{X} \equiv \mathbf{v}$$

$$v_k \equiv (\mathbf{Q}\boldsymbol{\pi})_k + \eta_k \sqrt{(\mathbf{Q}\boldsymbol{\Sigma}\mathbf{Q}')_{k,k}},$$

Market distribution

$\mathbf{X} \sim \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$ **returns on asset classes/funds**

Scenario analysis

$\mathbf{QX} \equiv \mathbf{v}$

Conditional formula

$$\mathbf{X}|\mathbf{v} \sim \mathrm{N}\left(\boldsymbol{\mu}_{\mathbf{x}|\mathbf{v}}, \boldsymbol{\Sigma}_{\mathbf{x}|\mathbf{v}}\right)$$

$$\begin{aligned}
\boldsymbol{\mu}_{\mathbf{x}|\mathbf{v}} &\equiv \boldsymbol{\mu} + \boldsymbol{\Sigma}\mathbf{Q}'\left(\mathbf{Q}\boldsymbol{\Sigma}\mathbf{Q}'\right)^{-1}(\mathbf{v} - \mathbf{Q}\boldsymbol{\mu}) \\
\boldsymbol{\Sigma}_{\mathbf{x}|\mathbf{v}} &\equiv \boldsymbol{\Sigma} - \boldsymbol{\Sigma}\mathbf{Q}'\left(\mathbf{Q}\boldsymbol{\Sigma}\mathbf{Q}'\right)^{-1}\mathbf{Q}\boldsymbol{\Sigma}.
\end{aligned}$$

Attilio Meucci - *Fully Flexible Views…* - related literature: scenario analysis

Market distribution

$\mathbf{X} \sim \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$ **returns on asset classes/funds**

Scenario analysis

$\mathbf{QX} \equiv \mathbf{v}$

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Optimization

$$\mathbf{w}_{\lambda} \equiv \underset{\mathbf{w}\in\mathcal{C}}{\operatorname{argmax}}\left\{\mathbf{w}'\boldsymbol{\mu}_{\mathbf{x}|\mathbf{v}} - \lambda\mathbf{w}'\boldsymbol{\Sigma}_{\mathbf{x}|\mathbf{v}}\mathbf{w}\right\}$$

Market distribution

$$\mathbf{X} \sim \mathrm{N}\left(\boldsymbol{\mu}, \boldsymbol{\Sigma}\right)$$ **returns on asset classes/funds**

$$\boldsymbol{\mu} \sim \mathrm{N}\left(\boldsymbol{\pi}, \tau\boldsymbol{\Sigma}\right)$$ **equilibrium**

Views

$$\mathbf{Q}\boldsymbol{\mu} \sim \mathrm{N}\left(\mathbf{v}, \boldsymbol{\Omega}\right)$$

Market distribution

$$\mathbf{X} \sim \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$$ **returns on asset classes/funds**

$$\boldsymbol{\mu} \sim \mathrm{N}(\boldsymbol{\pi}, \tau\boldsymbol{\Sigma})$$

Views

$$\mathbf{Q}\boldsymbol{\mu} \sim \mathrm{N}(\mathbf{v}, \boldsymbol{\Omega})$$

$$v_k \equiv (\mathbf{Q}\boldsymbol{\pi})_k + \eta_k \sqrt{(\mathbf{Q}\boldsymbol{\Sigma}\mathbf{Q}')_{k,k}},$$

$$\boldsymbol{\Omega} \equiv \frac{1}{c}\mathbf{Q}\boldsymbol{\Sigma}\mathbf{Q}'$$

Market distribution

$\mathbf{X} \sim \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$ **returns on asset classes/funds**

$\boldsymbol{\mu} \sim \mathrm{N}(\boldsymbol{\pi}, \tau\boldsymbol{\Sigma})$

Views

$\mathbf{Q}\boldsymbol{\mu} \sim \mathrm{N}(\mathbf{v}, \boldsymbol{\Omega})$

Bayes' formula

$$\mathbf{X}|\mathbf{v};\boldsymbol{\Omega} \sim \mathrm{N}(\boldsymbol{\mu}_{BL}, \boldsymbol{\Sigma}_{BL})$$

$$\begin{aligned} \boldsymbol{\mu}_{BL} &= \boldsymbol{\pi} + \tau\boldsymbol{\Sigma}\mathbf{Q}' \left(\tau\mathbf{Q}\boldsymbol{\Sigma}\mathbf{Q}' + \boldsymbol{\Omega}\right)^{-1} (\mathbf{v} - \mathbf{Q}\boldsymbol{\pi}) \\ \boldsymbol{\Sigma}_{BL} &= (1+\tau)\boldsymbol{\Sigma} - \tau^2\boldsymbol{\Sigma}\mathbf{Q}' \left(\tau\mathbf{Q}\boldsymbol{\Sigma}\mathbf{Q}' + \boldsymbol{\Omega}\right)^{-1} \mathbf{Q}\boldsymbol{\Sigma}. \end{aligned}$$

Market distribution

$$\mathbf{X} \sim \mathrm{N}\left(\boldsymbol{\mu}, \boldsymbol{\Sigma}\right)$$ **returns on asset classes/funds**

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Optimization

$$\mathbf{w}_\lambda \equiv \underset{\mathbf{w}\in\mathcal{C}}{\operatorname{argmax}}\left\{\mathbf{w}'\boldsymbol{\mu}_{BL} - \lambda\mathbf{w}'\boldsymbol{\Sigma}_{BL}\mathbf{w}\right\}$$

Market distribution

$\mathbf{X} \sim \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$ **returns on asset classes/funds**

Views/Scenarios

$\mathbf{Q}$ $\boldsymbol{\mu}$ $\equiv \mathbf{v}$ **+ uncertainty**

Optimization

$$\mathbf{w}_{\lambda} \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \left\{ \mathbf{w}' \boldsymbol{\mu} - \lambda \mathbf{w}' \boldsymbol{\Sigma} \mathbf{w} \right\}$$

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Market distribution | **Views/Scenarios**

$\mathbf{X} \sim \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$ **~~returns~~ on asset classes/funds** | $\mathbf{Q} \quad \boldsymbol{\mu} \quad \equiv \mathbf{v}$ **+ uncertainty**

Market is not just returns: implied volatilities (derivatives)
rates paths (mortgaves)
implied correlations (CDO's)
….

Optimization

$$\mathbf{w}_{\lambda} \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \left\{ \mathbf{w}'\boldsymbol{\mu} - \lambda \mathbf{w}'\boldsymbol{\Sigma}\mathbf{w} \right\}$$

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Market distribution

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Views/Scenarios

$\mathbf{Q} \quad \boldsymbol{\mu} \quad \equiv \mathbf{v}$ **+ uncertainty**

Market is not just returns

Market is not just normal: fat tails, skewness, tail-risk codependence,…

Optimization

$$\mathbf{w}_{\lambda} \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \left\{ \mathbf{w}' \boldsymbol{\mu} - \lambda \mathbf{w}' \boldsymbol{\Sigma} \mathbf{w} \right\}$$

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Market distribution	**Views/Scenarios**
$\mathbf{X} \sim \cancel{\mathrm{N}(\mu, \Sigma)}$ ~~returns~~ on asset classes/funds	$\mathbf{Q} \quad \mu \quad \equiv \mathbf{v}$ + uncertainty

Market is not just returns

Market is not just normal

Market is not just equilibrium: historical estimates, implied values, …

Optimization

$$\mathbf{w}_\lambda \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \{\mathbf{w}'\mu - \lambda \mathbf{w}'\Sigma\mathbf{w}\}$$

Market distribution

$\cancel{\mathbf{X} \sim \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})}$ ~~**returns on asset classes/funds**~~

Views/Scenarios

$\cancel{\mathbf{Q}}$ $\boldsymbol{\mu}$ $\equiv \mathbf{v}$ **+ uncertainty**

Market is not just returns

Market is not just normal

Market is not just equilibrium

Views are not just linear: generic functions

Optimization

$$\mathbf{w}_{\lambda} \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \left\{ \mathbf{w}'\boldsymbol{\mu} - \lambda \mathbf{w}'\boldsymbol{\Sigma}\mathbf{w} \right\}$$

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Market distribution

$\mathrm{X} \sim \cancel{\mathrm{N}(\mu, \Sigma)}$ **~~returns~~ on asset classes/funds**

Views/Scenarios

$\cancel{\mathrm{Q}}\ \cancel{\mu} \equiv \mathrm{v}$ **+ uncertainty**

Market is not just returns

Market is not just normal

Market is not just equilibrium

Views are not just linear

Views are not just on expectations: correlations,
volatilities,
tail behavior,
copulas,
…

Optimization

$$\mathrm{w}_\lambda \equiv \underset{\mathrm{w} \in \mathcal{C}}{\operatorname{argmax}} \left\{ \mathrm{w}'\mu - \lambda \mathrm{w}'\Sigma\mathrm{w} \right\}$$

Market distribution

$\mathbf{X} \sim \mathrm{N}(\mu, \Sigma)$ **returns on asset classes/funds**

Views/Scenarios

$\mathbf{Q}\mu \equiv \mathbf{v}$ **+ uncertainty**

Market is not just returns

Market is not just normal

Market is not just equilibrium

Views are not just linear

Views are not just on expectations

Views are not just equalities: stock ranking, qualitative views

Optimization

$$\mathbf{w}_{\lambda} \equiv \underset{\mathbf{w}\in\mathcal{C}}{\operatorname{argmax}} \left\{\mathbf{w}'\mu - \lambda\mathbf{w}'\Sigma\mathbf{w}\right\}$$

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Market distribution

$\cancel{\mathbf{X} \sim \mathrm{N}(\mu, \Sigma)}$ **~~returns on asset classes/funds~~**

Views/Scenarios

$\cancel{\mathbf{Q}}\ \cancel{\mu}\ \cancel{\equiv \mathbf{v}}$ **+ uncertainty**

Market is not just returns

Market is not just normal

Market is not just equilibrium

Views are not just linear

Views are not just on expectations

Views are not just equalities

Optimization is not just mean variance: mean-CVaR, mean-VaR, …

Optimization

$$\mathbf{w}_\lambda \equiv \cancel{\underset{\mathbf{w}\in\mathcal{C}}{\operatorname{argmax}}} \{\mathbf{w}'\mu - \lambda \mathbf{w}'\Sigma\mathbf{w}\}$$

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CONCLUSIONS

REFERENCES

e.g.

X_1 **2-yr swap rate**

X_2 **10-yr swap rate**

Market distr. $\mathbf{X} \sim f_{\mathbf{X}}$.

not returns, not normal, not equilibrium

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e.g.

X_1 **2-yr swap rate**

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Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ **not returns, not normal, not equilibrium**

Pricing $P_{t+\tau} \equiv P\left(\mathbf{X}, \mathcal{I}_t\right)$ **delta/gamma/vega, non-linear, …**

e.g.

duration + convexity

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Pricing $P_{t+\tau} \equiv P(\mathbf{X}, \mathcal{I}_t)$ **delta/gamma/vega, non-linear, …**

Optimization $\mathbf{w}^* \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \{\mathcal{S}(\mathbf{w}; f_{\mathbf{X}})\}$ **mean-CVaR trade-off, utility,…**

e.g.

duration + convexity

mean-variance

Market distr. $\mathbf{X} \sim f_{\mathbf{X}}$. **not returns, not normal, not equilibrium**

Focus $\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$ **non-linear functions and external factors**

e.g.

X_1 **2-yr swap rate**

X_2 **10-yr swap rate**

$V \equiv X_2 - X_1$ **slope**

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Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ **not returns, not normal, not equilibrium**

Focus $\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$ **non-linear functions and external factors**

Views $\mathbf{V} \sim \tilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}.$ **full distribution specification**

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$\widetilde{m}\{V_k\} \gtreqless \widetilde{\mu}_{\mathbf{v},k}$: **view on expectations (BL), medians**

e.g.

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$\widetilde{m}\{V_1\} \geq \widetilde{m}\{V_2\} \geq \cdots \geq \widetilde{m}\{V_K\}$ **ranking**

e.g.

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$\widetilde{m}\{V_1\} \geq \widetilde{m}\{V_2\} \geq \cdots \geq \widetilde{m}\{V_K\}$ **ranking**

$\widetilde{\sigma}\{V_k\} \gtreqless \varkappa\sigma\{V_k\}$ **views on volatilities**

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Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ **not returns, not normal, not equilibrium**

Focus $\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$ **non-linear functions and external factors**

Views $\mathbf{V} \sim \tilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}.$ **full distribution specification**

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$\widetilde{m}\{V_1\} \geq \widetilde{m}\{V_2\} \geq \cdots \geq \widetilde{m}\{V_K\}$ **ranking**

$\widetilde{\sigma}\{V_k\} \gtreqqless \varkappa\sigma\{V_k\}$ **views on volatilities**

$\widetilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1 \mathbf{I} + \rho_2 \mathbb{C}\{\mathbf{V}\} + \rho_3 \mathbf{1}\mathbf{1}',$ **correlation stress-testing**

e.g.

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Focus $\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$ **non-linear functions and external factors**

Views $\mathbf{V} \sim \tilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}.$ **full distribution specification**

$\widetilde{m}\{V_k\} \gtreqqless \widetilde{\mu}_{\mathbf{v},k}:$ **view on expectations (BL), medians**

$\widetilde{m}\{V_1\} \geq \widetilde{m}\{V_2\} \geq \cdots \geq \widetilde{m}\{V_K\}$ **ranking**

$\widetilde{\sigma}\{V_k\} \gtreqqless \varkappa\sigma\{V_k\}$ **views on volatilities**

$\widetilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1\mathbf{I} + \rho_2\mathbb{C}\{\mathbf{V}\} + \rho_3\mathbf{1}\mathbf{1}',$ **correlation stress-testing**

$\widetilde{Q}_V(u) \gtreqqless Q_V(u)$ **view on tail behavior**

e.g.

X_1 **2-yr swap rate**

X_2 **10-yr swap rate**

$V \equiv X_2 - X_1$ **slope**

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Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ **not returns, not normal, not equilibrium**

Focus $\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$ **non-linear functions and external factors**

Views $\mathbf{V} \sim \widetilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}.$ **full distribution specification**

$$\left.\begin{array}{l}
\widetilde{m}\left\{V_k\right\} \gtreqless \widetilde{\mu}_{\mathbf{v},k}; \\[1em]
\widetilde{m}\left\{V_1\right\} \geq \widetilde{m}\left\{V_2\right\} \geq \cdots \geq \widetilde{m}\left\{V_K\right\} \\[1em]
\widetilde{\sigma}\left\{V_k\right\} \gtreqless \varkappa\sigma\left\{V_k\right\} \\[1em]
\widetilde{\mathbb{C}}\left\{\mathbf{V}\right\} \equiv \rho_1\mathbf{I} + \rho_2\mathbb{C}\left\{\mathbf{V}\right\} + \rho_3\mathbf{1}\mathbf{1}', \\[1em]
\widetilde{Q}_V\left(u\right) \gtreqless Q_V\left(u\right)
\end{array}\right\}$$

partial distribution specification

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Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ **not returns, not normal, not equilibrium**

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&\widetilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1 \mathbf{I} + \rho_2 \mathbb{C}\{\mathbf{V}\} + \rho_3 \mathbf{1}\mathbf{1}',\\
&\widetilde{Q}_V(u) \gtreqless Q_V(u)
\end{aligned}\right\}$$

partial distribution specification

(negative) relative entropy $\mathcal{E}\left(\widetilde{f}_{\mathbf{X}}, f_{\mathbf{X}}\right) \equiv \int \widetilde{f}_{\mathbf{X}}(\mathrm{x})\left[\ln \widetilde{f}_{\mathbf{X}}(\mathrm{x}) - \ln f_{\mathbf{X}}(\mathrm{x})\right] d\mathrm{x}.$

- distance btw. distributions $\widetilde{f}_{\mathbf{X}}, f_{\mathbf{X}}$

- structure imposed on $\widetilde{f}_{\mathbf{X}}$

- generalize Bayesian approach

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Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ **not returns, not normal, not equilibrium**

Focus $\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$ **non-linear functions and external factors**

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\widetilde{Q}_V(u) \gtreqless Q_V(u)
\end{array}\right\}$$

partial distribution specification

Posterior $\widetilde{f}_{\mathbf{X}} \equiv \boxed{\operatorname{argmin}\{\mathcal{E}(f, f_{\mathbf{X}})\}}$ **least distance from prior**

(negative) relative entropy $\mathcal{E}\left(\widetilde{f}_{\mathbf{X}}, f_{\mathbf{X}}\right) \equiv \int \widetilde{f}_{\mathbf{X}}(\mathrm{x}) \left[\ln \widetilde{f}_{\mathbf{X}}(\mathrm{x}) - \ln f_{\mathbf{X}}(\mathrm{x})\right] d\mathrm{x}.$

- **distance btw. distributions** $\widetilde{f}_{\mathbf{X}}, f_{\mathbf{X}}$
- **structure imposed on** $\widetilde{f}_{\mathbf{X}}$
- **generalize Bayesian approach**

Attilio Meucci - *Fully Flexible Views…* - entropy pooling

Market distr. $\mathbf{X} \sim f_{\mathbf{X}}$. **not returns, not normal, not equilibrium**

Focus $\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$ **non-linear functions and external factors**

Views $\mathbf{V} \sim \widetilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}$. **full distribution specification**

$$\widetilde{m}\{V_k\} \gtreqless \widetilde{\mu}_{\mathbf{v},k};$$

$$\widetilde{m}\{V_1\} \geq \widetilde{m}\{V_2\} \geq \cdots \geq \widetilde{m}\{V_K\}$$

$$\widetilde{\sigma}\{V_k\} \gtreqless \varkappa\sigma\{V_k\}$$

$$\widetilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1\mathbf{I} + \rho_2\mathbb{C}\{\mathbf{V}\} + \rho_3\mathbf{1}\mathbf{1}',$$

$$\widetilde{Q}_V(u) \gtreqless Q_V(u)$$

partial distribution specification

Posterior $\widetilde{f}_{\mathbf{X}} \equiv \underset{\boxed{f \in \mathbb{V}}}{\operatorname{argmin}} \{\mathcal{E}(f, f_{\mathbf{X}})\}$ **least distance from prior, views satisfied**

(negative) relative entropy $\mathcal{E}\left(\widetilde{f}_{\mathbf{X}}, f_{\mathbf{X}}\right) \equiv \int \widetilde{f}_{\mathbf{X}}(\mathrm{x}) \left[\ln \widetilde{f}_{\mathbf{X}}(\mathrm{x}) - \ln f_{\mathbf{X}}(\mathrm{x})\right] d\mathrm{x}.$

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- **generalize Bayesian approach**

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e.g.

X_1 **2-yr swap rate**

X_2 **10-yr swap rate**

$V \equiv X_2 - X_1$ **slope**

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\widetilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1 \mathbf{I} + \rho_2 \mathbb{C}\{\mathbf{V}\} + \rho_3 \mathbf{1}\mathbf{1}', \\
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X_2 **10-yr swap rate**

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Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ **not returns, not normal, not equilibrium**

Focus $\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$ **non-linear functions and external factors**

Views $\mathbf{V} \sim \widetilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}.$ **full distribution specification**

$$\left.\begin{array}{l}
\widetilde{m}\{V_k\} \gtreqless \widetilde{\mu}_{\mathbf{v},k}: \\
\widetilde{m}\{V_1\} \geq \widetilde{m}\{V_2\} \geq \cdots \geq \widetilde{m}\{V_K\} \\
\widetilde{\sigma}\{V_k\} \gtreqless \varkappa\sigma\{V_k\} \\
\widetilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1\mathbf{I} + \rho_2\mathbb{C}\{\mathbf{V}\} + \rho_3\mathbf{11}', \\
\widetilde{Q}_V(u) \gtreqless Q_V(u)
\end{array}\right\}$$

partial distribution specification

Posterior $\widetilde{f}_{\mathbf{X}} \equiv \underset{f\in\mathbb{V}}{\operatorname{argmin}}\{\mathcal{E}(f, f_{\mathbf{X}})\}$ **least distance from prior, views satisfied**

Confidence $\widetilde{f}^c_{\mathbf{X}} \equiv (1-c) f_{\mathbf{X}} + c\widetilde{f}_{\mathbf{X}}.$ **multi-user, multi-confidence**

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Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ **not returns, not normal, not equilibrium**

Focus $\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$ **non-linear functions and external factors**

e.g.

X_1 **2-yr swap rate**

X_2 **10-yr swap rate**

$V \equiv X_2 - X_1$ **slope**

Views $\mathbf{V} \sim \widetilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}.$ **full distribution specification**

$$\left.\begin{aligned}
&\widetilde{m}\{V_k\} \gtreqless \widetilde{\mu}_{\mathbf{v},k}: \\
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&\widetilde{\sigma}\{V_k\} \gtreqless \varkappa\sigma\{V_k\} \\
&\widetilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1\mathbf{I} + \rho_2\mathbb{C}\{\mathbf{V}\} + \rho_3\mathbf{1}\mathbf{1}', \\
&\widetilde{Q}_V(u) \gtreqless Q_V(u)
\end{aligned}\right\}$$

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Pricing $P_{t+\tau} \equiv P\left(\widetilde{\mathbf{X}}, \mathcal{I}_t\right)$ **delta/gamma/vega, non-linear, …**

e.g.

duration + convexity

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Market distr. $\mathbf{X} \sim f_{\mathbf{X}}$. **not returns, not normal, not equilibrium**

Focus $\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$ **non-linear functions and external factors**

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$$\tilde{m}\{V_k\} \gtreqless \tilde{\mu}_{\mathbf{v},k};$$

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Pricing $P_{t+\tau} \equiv P(\tilde{\mathbf{X}}, \mathcal{I}_t)$ **delta/gamma/vega, non-linear, …**

Optimization $\mathbf{w}^* \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}}\{\mathcal{S}(\mathbf{w}; \tilde{f}^c_{\mathbf{X}})\}$ **mean-CVaR trade-off, …**

e.g.

X_1 **2-yr swap rate**

X_2 **10-yr swap rate**

$V \equiv X_2 - X_1$ **slope**

e.g.

duration + convexity

mean-variance

Attilio Meucci - *Fully Flexible Views…* - analytical solution

Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ $\mathbf{X} \sim \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$

Focus $\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$

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$$\widetilde{m}\{V_k\} \gtreqless \widetilde{\mu}_{\mathbf{v},k}:$$

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$$\widetilde{\sigma}\{V_k\} \gtreqless \varkappa\sigma\{V_k\}$$

$$\widetilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1 \mathbf{I} + \rho_2 \mathbb{C}\{\mathbf{V}\} + \rho_3 \mathbf{1}\mathbf{1}',$$

$$\widetilde{Q}_V(u) \gtreqless Q_V(u)$$

Posterior $\widetilde{f}_{\mathbf{X}} \equiv \underset{f \in \mathbb{V}}{\operatorname{argmin}} \{\mathcal{E}(f, f_{\mathbf{X}})\}$

Confidence $\widetilde{f}_{\mathbf{X}}^{c} \equiv (1-c) f_{\mathbf{X}} + c\widetilde{f}_{\mathbf{X}}.$

Pricing $P_{t+\tau} \equiv P(\widetilde{\mathbf{X}}, \mathcal{I}_t)$

Optimization $\mathbf{w}^* \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \{\mathcal{S}(\mathbf{w}; \widetilde{f}_{\mathbf{X}}^{c})\}$

Attilio Meucci - *Fully Flexible Views…* - analytical solution

Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ $\quad\quad$ $\mathbf{X} \sim \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$

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Posterior $\widetilde{f}_{\mathbf{X}} \equiv \underset{f \in \mathbb{V}}{\operatorname{argmin}}\{\mathcal{E}(f, f_{\mathbf{X}})\}$

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Attilio Meucci - *Fully Flexible Views…* - analytical solution

Market distr.	$\mathbf{X} \sim f_{\mathbf{X}}.$	$\mathbf{X} \sim \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$
Focus	$\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$	$\mathbf{QX} \quad \mathbf{GX}$
Views	$\mathbf{V} \sim \widetilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}.$ $\widetilde{m}\{V_k\} \gtreqless \widetilde{\mu}_{\mathbf{v},k}.$ $\widetilde{m}\{V_1\} \geq \widetilde{m}\{V_2\} \geq \cdots \geq \widetilde{m}\{V_K\}$ $\widetilde{\sigma}\{V_k\} \gtreqless \varkappa\sigma\{V_k\}$ $\widetilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1\mathbf{I} + \rho_2\mathbb{C}\{\mathbf{V}\} + \rho_3\mathbf{1}\mathbf{1}',$ $\widetilde{Q}_V(u) \gtreqless Q_V(u)$	$\mathbb{E}\{\mathbf{QX}\} \equiv \widetilde{\boldsymbol{\mu}}_{\mathbf{Q}}$ $\mathbb{C}ov\{\mathbf{GX}\} \equiv \widetilde{\boldsymbol{\Sigma}}_{\mathbf{G}}$
Posterior	$\widetilde{f}_{\mathbf{X}} \equiv \underset{f \in \mathbb{V}}{\operatorname{argmin}} \{\mathcal{E}(f, f_{\mathbf{X}})\}$	
Confidence	$\widetilde{f}^c_{\mathbf{X}} \equiv (1-c) f_{\mathbf{X}} + c\widetilde{f}_{\mathbf{X}}.$	
Pricing	$P_{t+\tau} \equiv P(\widetilde{\mathbf{X}}, \mathcal{I}_t)$	
Optimization	$\mathbf{w}^* \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \{\mathcal{S}(\mathbf{w}; \widetilde{f}^c_{\mathbf{X}})\}$	

Attilio Meucci - *Fully Flexible Views…* - analytical solution

Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ $\mathbf{X} \sim \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$

Focus $\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$ $\mathbf{QX}$ $\mathbf{GX}$

Views $\mathbf{V} \sim \widetilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}.$

$\widetilde{m}\{V_k\} \gtreqless \widetilde{\mu}_{\mathbf{v},k};$

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$\mathbb{E}\{\mathbf{QX}\} \equiv \widetilde{\boldsymbol{\mu}}_{\mathbf{Q}}$

$\mathbb{C}ov\{\mathbf{GX}\} \equiv \widetilde{\boldsymbol{\Sigma}}_{\mathbf{G}}$

Posterior $\widetilde{f}_{\mathbf{X}} \equiv \underset{f \in \mathbb{V}}{\operatorname{argmin}} \{\mathcal{E}(f, f_{\mathbf{X}})\}$ $\mathbf{X} \sim \mathrm{N}\left(\widetilde{\boldsymbol{\mu}}, \widetilde{\boldsymbol{\Sigma}}\right)$

$$\left\{\begin{array}{lll} \widetilde{\boldsymbol{\mu}} & \equiv & \boldsymbol{\mu} + \boldsymbol{\Sigma}\mathbf{Q}'\left(\mathbf{Q}\boldsymbol{\Sigma}\mathbf{Q}'\right)^{-1}\left(\widetilde{\boldsymbol{\mu}}_{\mathbf{Q}} - \mathbf{Q}\boldsymbol{\mu}\right) \\ \widetilde{\boldsymbol{\Sigma}} & \equiv & \boldsymbol{\Sigma} + \boldsymbol{\Sigma}\mathbf{G}'\left(\left(\mathbf{G}\boldsymbol{\Sigma}\mathbf{G}'\right)^{-1}\widetilde{\boldsymbol{\Sigma}}_{\mathbf{G}}\left(\mathbf{G}\boldsymbol{\Sigma}\mathbf{G}'\right)^{-1} \right. \\ & & \left. - \left(\mathbf{G}\boldsymbol{\Sigma}\mathbf{G}'\right)^{-1}\right)\mathbf{G}\boldsymbol{\Sigma}. \end{array}\right.$$

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Pricing $P_{t+\tau} \equiv P\left(\widetilde{\mathbf{X}}, \mathcal{I}_t\right)$

Optimization $\mathbf{w}^* \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \left\{\mathcal{S}\left(\mathbf{w}; \widetilde{f}_{\mathbf{X}}^{c}\right)\right\}$

Attilio Meucci - *Fully Flexible Views…* - analytical solution

Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ $\qquad$ $\mathbf{X} \sim \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma})$

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Posterior $\widetilde{f}_{\mathbf{X}} \equiv \underset{f \in \mathbb{V}}{\operatorname{argmin}} \{\mathcal{E}(f, f_{\mathbf{X}})\}$ $\qquad$ $\mathbf{X} \sim \mathrm{N}\left(\widetilde{\boldsymbol{\mu}}, \widetilde{\boldsymbol{\Sigma}}\right)$

$$\left\{\begin{array}{lcl} \widetilde{\boldsymbol{\mu}} & \equiv & \boldsymbol{\mu} + \boldsymbol{\Sigma}\mathbf{Q}'\left(\mathbf{Q}\boldsymbol{\Sigma}\mathbf{Q}'\right)^{-1}\left(\widetilde{\boldsymbol{\mu}}_{\mathbf{Q}} - \mathbf{Q}\boldsymbol{\mu}\right) \\ \widetilde{\boldsymbol{\Sigma}} & \equiv & \boldsymbol{\Sigma} + \boldsymbol{\Sigma}\mathbf{G}'\left(\left(\mathbf{G}\boldsymbol{\Sigma}\mathbf{G}'\right)^{-1}\widetilde{\boldsymbol{\Sigma}}_{\mathbf{G}}\left(\mathbf{G}\boldsymbol{\Sigma}\mathbf{G}'\right)^{-1} \right. \\ & & \left. - \left(\mathbf{G}\boldsymbol{\Sigma}\mathbf{G}'\right)^{-1}\right)\mathbf{G}\boldsymbol{\Sigma}. \end{array}\right.$$

Confidence $\widetilde{f}_{\mathbf{X}}^{c} \equiv (1-c) f_{\mathbf{X}} + c\widetilde{f}_{\mathbf{X}}.$

$$\mathbf{X} \sim \begin{cases} \mathrm{N}(\boldsymbol{\mu}, \boldsymbol{\Sigma}) & (\text{probability: } 1-c) \\ \mathrm{N}\left(\widetilde{\boldsymbol{\mu}}, \widetilde{\boldsymbol{\Sigma}}\right) & (\text{probability: } c) \end{cases}$$

Pricing $P_{t+\tau} \equiv P\left(\widetilde{\mathbf{X}}, \mathcal{I}_t\right)$

Optimization $\mathbf{w}^* \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \left\{\mathcal{S}\left(\mathbf{w}; \widetilde{f}_{\mathbf{X}}^{c}\right)\right\}$

Attilio Meucci - *Fully Flexible Views…* - analytical solution

Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ $\qquad$ $\mathbf{X} \sim \mathrm{N}(\mu, \Sigma)$

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$\mathbb{E}\{\mathbf{QX}\} \equiv \widetilde{\mu}_{\mathbf{Q}}$

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Posterior $\widetilde{f}_{\mathbf{X}} \equiv \underset{f \in \mathbb{V}}{\operatorname{argmin}} \{\mathcal{E}(f, f_{\mathbf{X}})\}$ $\qquad$ $\mathbf{X} \sim \mathrm{N}\left(\widetilde{\mu}, \widetilde{\Sigma}\right)$

$$\begin{cases} \widetilde{\mu} & \equiv \quad \mu + \Sigma \mathbf{Q}' \left(\mathbf{Q}\Sigma\mathbf{Q}'\right)^{-1} \left(\widetilde{\mu}_{\mathbf{Q}} - \mathbf{Q}\mu\right) \\ \widetilde{\Sigma} & \equiv \quad \Sigma + \Sigma \mathbf{G}' \left(\left(\mathbf{G}\Sigma\mathbf{G}'\right)^{-1} \widetilde{\Sigma}_{\mathbf{G}} \left(\mathbf{G}\Sigma\mathbf{G}'\right)^{-1} - \left(\mathbf{G}\Sigma\mathbf{G}'\right)^{-1}\right) \mathbf{G}\Sigma. \end{cases}$$

Confidence $\widetilde{f}^{c}_{\mathbf{X}} \equiv (1-c) f_{\mathbf{X}} + c\widetilde{f}_{\mathbf{X}}.$

$$\mathbf{X} \sim \begin{cases} \mathrm{N}(\mu, \Sigma) & (\text{probability: } 1-c) \\ \mathrm{N}\left(\widetilde{\mu}, \widetilde{\Sigma}\right) & (\text{probability: } c) \end{cases}$$

Pricing $P_{t+\tau} \equiv P\left(\widetilde{\mathbf{X}}, \mathcal{I}_t\right)$ $\qquad$ …

Optimization $\mathbf{w}^* \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \left\{\mathcal{S}\left(\mathbf{w}; \widetilde{f}^{c}_{\mathbf{X}}\right)\right\}$ $\qquad$ …

RELATED LITERATURE

UNIFIED FRAMEWORK: ENTROPY POOLING

ANALYTICAL SOLUTION

FULLY GENERAL IMPLEMENTATION

CASE STUDIES: RANKING ALLOCATION, OPTION TRADING

CONCLUSIONS

REFERENCES

Market distr. $\mathbf{X} \sim f_{\mathbf{X}}$ $\Leftrightarrow$ $\mathcal{X}$ $J \times N$ panel $\mathbf{p}$ probabilities $1/J$

Market distr. $\mathbf{X} \sim f_{\mathbf{X}}$. $\Longleftrightarrow$ $\mathcal{X}$ $J \times N$ panel $\mathbf{p}$ probabilities $1/J$.

Pricing $P_{t+\tau} \equiv P(\mathbf{X}, \mathcal{I}_t)$ $\Longleftrightarrow$ $\mathcal{P}$ $\mathbf{p}$

Optimization $\mathbf{w}^* \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \{\mathcal{S}(\mathbf{w}; f_{\mathbf{X}})\}$ $\Longleftrightarrow$ ...

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Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ $\Longleftrightarrow$ $\mathcal{X}$ $J \times N$ panel $\mathbf{p}$ probabilities $1/J$;

Focus $\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$

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Pricing $P_{t+\tau} \equiv P(\widetilde{\mathbf{X}}, \mathcal{I}_t)$

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scenario index

Views $\mathbf{V} \sim \widetilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}.$

$$\widetilde{m}\{V_k\} \gtreqless \widetilde{\mu}_{\mathbf{v},k}:$$

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Pricing $P_{t+\tau} \equiv P(\widetilde{\mathbf{X}}, \mathcal{I}_t)$

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Views

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\tilde{Q}_V(u) \gtreqless Q_V(u)
\end{array}\right\} \Longleftrightarrow \quad \underline{\mathbf{a}} \leq \mathbf{A}\tilde{\mathbf{p}} \leq \overline{\mathbf{a}}.$$

e.g.

X_1 **2-yr swap rate**

X_2 **10-yr swap rate**

$V \equiv X_2 - X_1$ **slope**

$$\tilde{m}\{V\} \equiv \tilde{\mu}$$

$$\Updownarrow$$

$$\tilde{\mu} \leq \sum_{j=1}^{J} \mathcal{V}_j \tilde{p}_j \leq \tilde{\mu}$$

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Optimization $\mathbf{w}^* \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \left\{\mathcal{S}\left(\mathbf{w}; \tilde{f}^c_{\mathbf{X}}\right)\right\}$

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\widetilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1 \mathbf{I} + \rho_2 \mathbb{C}\{\mathbf{V}\} + \rho_3 \mathbf{1}\mathbf{1}',\\
\widetilde{Q}_V(u) \gtreqless Q_V(u)
\end{array}\right\} \Longleftrightarrow \underline{\mathbf{a}} \leq \mathbf{A}\widetilde{\mathbf{p}} \leq \overline{\mathbf{a}}.$$

Posterior $\widetilde{f}_{\mathbf{X}} \equiv \underset{f \in \mathbb{V}}{\operatorname{argmin}} \{\mathcal{E}(f, f_{\mathbf{X}})\}$

$$\mathcal{E}\left(\widetilde{f}_{\mathbf{X}}, f_{\mathbf{X}}\right) \equiv \int \widetilde{f}_{\mathbf{X}}(\mathrm{x}) \left[\ln \widetilde{f}_{\mathbf{X}}(\mathrm{x}) - \ln f_{\mathbf{X}}(\mathrm{x})\right] d\mathrm{x}.$$

Attilio Meucci - *Fully Flexible Views…* - implementation

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Views

$$\mathbf{V} \sim \widetilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}.$$

$$\left.\begin{array}{l} \widetilde{m}\{V_k\} \gtreqless \widetilde{\mu}_{\mathbf{v},k}; \\ \widetilde{m}\{V_1\} \geq \widetilde{m}\{V_2\} \geq \cdots \geq \widetilde{m}\{V_K\} \\ \widetilde{\sigma}\{V_k\} \gtreqless \varkappa\sigma\{V_k\} \\ \widetilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1\mathbf{I} + \rho_2\mathbb{C}\{\mathbf{V}\} + \rho_3\mathbf{1}\mathbf{1}', \\ \widetilde{Q}_V(u) \gtreqless Q_V(u) \end{array}\right\} \Longleftrightarrow \quad \underline{\mathbf{a}} \leq \mathbf{A}\widetilde{\mathbf{p}} \leq \overline{\mathbf{a}}.$$

Posterior $\widetilde{f}_{\mathbf{X}} \equiv \underset{f \in \mathbb{V}}{\operatorname{argmin}} \{\mathcal{E}(f, f_{\mathbf{X}})\}$

$$\mathcal{E}\left(\widetilde{f}_{\mathbf{X}}, f_{\mathbf{X}}\right) \equiv \int \widetilde{f}_{\mathbf{X}}(\mathrm{x}) \left[\ln \widetilde{f}_{\mathbf{X}}(\mathrm{x}) - \ln f_{\mathbf{X}}(\mathrm{x})\right] d\mathrm{x}. \quad \Longleftrightarrow \quad \mathcal{E}(\widetilde{\mathbf{p}}, \mathbf{p}) \equiv \sum_{j=1}^{J} \widetilde{p}_j \left[\ln(\widetilde{p}_j) - \ln(p_j)\right]$$

Attilio Meucci - *Fully Flexible Views…* - implementation

Market distr. $\mathbf{X} \sim f_{\mathbf{X}}.$ $\quad\Longleftrightarrow\quad$ $\mathcal{X}$ $J \times N$ panel $\quad$ $\mathbf{p}$ probabilities $1/J.$

Focus $\mathbf{V} \equiv \mathbf{g}\left(\mathbf{X}\right) \sim f_{\mathbf{V}}$ $\quad\Longleftrightarrow\quad$ $\mathcal{V}_{j,k} \equiv g_k\left(\mathcal{X}_{j,1}, \ldots, \mathcal{X}_{j,N}\right)$

Views

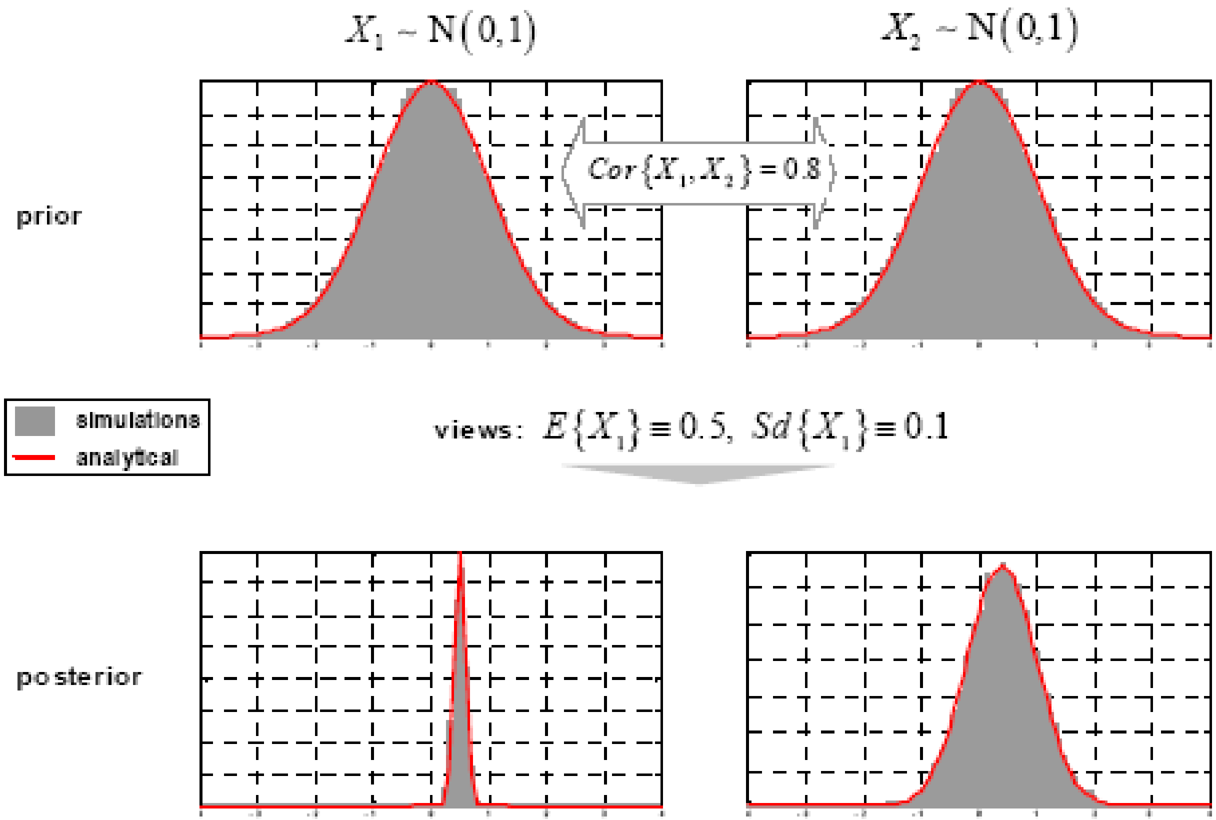
$$\mathbf{V} \sim \widetilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}.$$

$$\left.\begin{array}{l}
\widetilde{m}\left\{V_k\right\} \gtreqless \widetilde{\mu}_{\mathbf{v},k}; \\
\widetilde{m}\left\{V_1\right\} \geq \widetilde{m}\left\{V_2\right\} \geq \cdots \geq \widetilde{m}\left\{V_K\right\} \\
\widetilde{\sigma}\left\{V_k\right\} \gtreqless \varkappa\sigma\left\{V_k\right\} \\
\widetilde{\mathbb{C}}\left\{\mathbf{V}\right\} \equiv \rho_1\mathbf{I} + \rho_2\mathbb{C}\left\{\mathbf{V}\right\} + \rho_3\mathbf{1}\mathbf{1}', \\
\widetilde{Q}_V\left(u\right) \gtreqless Q_V\left(u\right)
\end{array}\right\} \quad\Longleftrightarrow\quad \underline{\mathbf{a}} \leq \mathbf{A}\widetilde{\mathbf{p}} \leq \overline{\mathbf{a}}.$$

Posterior $\widetilde{f}_{\mathbf{X}} \equiv \underset{f \in \mathbb{V}}{\operatorname{argmin}}\left\{\mathcal{E}\left(f, f_{\mathbf{X}}\right)\right\}$ $\quad\Longleftrightarrow\quad$ $\mathcal{X}$ $\quad$ $\widetilde{\mathbf{p}} \equiv \underset{\underline{\mathbf{a}} \leq \mathbf{A}\mathbf{f} \leq \overline{\mathbf{a}}}{\operatorname{argmin}}\left\{\mathcal{E}\left(\mathbf{f}, \mathbf{p}\right)\right\}$

$$\mathcal{E}\left(\widetilde{f}_{\mathbf{X}}, f_{\mathbf{X}}\right) \equiv \int \widetilde{f}_{\mathbf{X}}\left(\mathrm{x}\right)\left[\ln \widetilde{f}_{\mathbf{X}}\left(\mathrm{x}\right) - \ln f_{\mathbf{X}}\left(\mathrm{x}\right)\right] d\mathrm{x}. \quad\Longleftrightarrow\quad \mathcal{E}\left(\widetilde{\mathbf{p}}, \mathbf{p}\right) \equiv \sum_{j=1}^{J} \widetilde{p}_j\left[\ln\left(\widetilde{p}_j\right) - \ln\left(p_j\right)\right]$$

Attilio Meucci - *Fully Flexible Views…* - implementation



Posterior $\widetilde{f}_{\mathbf{X}} \equiv \underset{f \in \mathbb{V}}{\operatorname{argmin}} \{\mathcal{E}(f, f_{\mathbf{X}})\}$ $\Leftrightarrow$ $\mathcal{X}$ $\boxed{\widetilde{\mathbf{p}} \equiv \underset{\underline{\mathbf{a}} \leq \mathbf{A}\mathbf{f} \leq \overline{\mathbf{a}}}{\operatorname{argmin}} \{\mathcal{E}(\mathbf{f}, \mathbf{p})\}}$

Dual formulation: linearly constrained convex optimization in # variables = # views

Attilio Meucci - *Fully Flexible Views…* - implementation

Market distr.	$\mathbf{X} \sim f_{\mathbf{X}}$.	$\Leftrightarrow$	$\mathcal{X}$ $J \times N$ panel $\quad \mathbf{p}$ probabilities $1/J$.
Focus	$\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$	$\Leftrightarrow$	$\mathcal{V}_{j,k} \equiv g_k(\mathcal{X}_{j,1}, \ldots, \mathcal{X}_{j,N})$
Views	$\mathbf{V} \sim \widetilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}$. $\widetilde{m}\{V_k\} \gtreqless \widetilde{\mu}_{\mathbf{v},k}$; $\widetilde{m}\{V_1\} \geq \widetilde{m}\{V_2\} \geq \cdots \geq \widetilde{m}\{V_K\}$ $\widetilde{\sigma}\{V_k\} \gtreqless \varkappa\sigma\{V_k\}$ $\widetilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1 \mathbf{I} + \rho_2 \mathbb{C}\{\mathbf{V}\} + \rho_3 \mathbf{1}\mathbf{1}'$, $\widetilde{Q}_V(u) \gtreqless Q_V(u)$	$\Leftrightarrow$	$\underline{\mathbf{a}} \leq \mathbf{A}\widetilde{\mathbf{p}} \leq \overline{\mathbf{a}}$.
Posterior	$\widetilde{f}_{\mathbf{X}} \equiv \underset{f \in \mathbb{V}}{\operatorname{argmin}} \{\mathcal{E}(f, f_{\mathbf{X}})\}$	$\Leftrightarrow$	$\mathcal{X} \quad \widetilde{\mathbf{p}} \equiv \underset{\underline{\mathbf{a}} \leq \mathbf{A}\mathbf{f} \leq \overline{\mathbf{a}}}{\operatorname{argmin}} \{\mathcal{E}(\mathbf{f}, \mathbf{p})\}$
Confidence	$\widetilde{f}^c_{\mathbf{X}} \equiv (1-c) f_{\mathbf{X}} + c\widetilde{f}_{\mathbf{X}}$.		
Pricing	$P_{t+\tau} \equiv P(\widetilde{\mathbf{X}}, \mathcal{I}_t)$		
Optimization	$\mathbf{w}^* \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \{\mathcal{S}(\mathbf{w}; \widetilde{f}^c_{\mathbf{X}})\}$		

Attilio Meucci - *Fully Flexible Views…* - implementation

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Views

$$\left.\begin{array}{l} \mathbf{V} \sim \widetilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}. \\ \widetilde{m}\{V_k\} \gtreqless \widetilde{\mu}_{\mathbf{v},k}; \\ \widetilde{m}\{V_1\} \geq \widetilde{m}\{V_2\} \geq \cdots \geq \widetilde{m}\{V_K\} \\ \widetilde{\sigma}\{V_k\} \gtreqless \varkappa\sigma\{V_k\} \\ \widetilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1 \mathbf{I} + \rho_2 \mathbb{C}\{\mathbf{V}\} + \rho_3 \mathbf{1}\mathbf{1}', \\ \widetilde{Q}_V(u) \gtreqless Q_V(u) \end{array}\right\} \Longleftrightarrow \underline{\mathbf{a}} \leq \mathbf{A}\widetilde{\mathbf{p}} \leq \overline{\mathbf{a}}.$$

Posterior $\widetilde{f}_{\mathbf{X}} \equiv \underset{f \in \mathbb{V}}{\operatorname{argmin}} \{\mathcal{E}(f, f_{\mathbf{X}})\}$ $\Longleftrightarrow$ $\mathcal{X}$ $\widetilde{\mathbf{p}} \equiv \underset{\underline{\mathbf{a}} \leq \mathbf{A}\mathbf{f} \leq \overline{\mathbf{a}}}{\operatorname{argmin}} \{\mathcal{E}(\mathbf{f}, \mathbf{p})\}$

Confidence $\widetilde{f}_{\mathbf{X}}^{c} \equiv (1-c) f_{\mathbf{X}} + c\widetilde{f}_{\mathbf{X}}$. $\Longleftrightarrow$ $\mathcal{X}$ $\mathbf{p}_c \equiv (1-c)\mathbf{p} + c\widetilde{\mathbf{p}}$.

Pricing $P_{t+\tau} \equiv P(\widetilde{\mathbf{X}}, \mathcal{I}_t)$

Optimization $\mathbf{w}^* \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \{\mathcal{S}(\mathbf{w}; \widetilde{f}_{\mathbf{X}}^{c})\}$

Attilio Meucci - *Fully Flexible Views…* - implementation

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Views	$\mathbf{V} \sim \tilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}.$ $\tilde{m}\{V_k\} \gtreqless \tilde{\mu}_{\mathbf{v},k};$ $\tilde{m}\{V_1\} \geq \tilde{m}\{V_2\} \geq \cdots \geq \tilde{m}\{V_K\}$ $\tilde{\sigma}\{V_k\} \gtreqless \varkappa\sigma\{V_k\}$ $\tilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1 \mathbf{I} + \rho_2 \mathbb{C}\{\mathbf{V}\} + \rho_3 \mathbf{1}\mathbf{1}',$ $\tilde{Q}_V(u) \gtreqless Q_V(u)$	$\Longleftrightarrow$	$\underline{\mathbf{a}} \leq \mathbf{A}\tilde{\mathbf{p}} \leq \overline{\mathbf{a}}.$
Posterior	$\tilde{f}_{\mathbf{X}} \equiv \underset{f \in \mathbb{V}}{\operatorname{argmin}} \{\mathcal{E}(f, f_{\mathbf{X}})\}$	$\Longleftrightarrow$	$\mathcal{X} \quad \tilde{\mathbf{p}} \equiv \underset{\underline{\mathbf{a}} \leq \mathbf{A}\mathbf{f} \leq \overline{\mathbf{a}}}{\operatorname{argmin}} \{\mathcal{E}(\mathbf{f}, \mathbf{p})\}$
Confidence	$\tilde{f}^c_{\mathbf{X}} \equiv (1-c) f_{\mathbf{X}} + c\tilde{f}_{\mathbf{X}}.$	$\Longleftrightarrow$	$\mathcal{X} \quad \mathbf{p}_c \equiv (1-c)\mathbf{p} + c\tilde{\mathbf{p}}.$
~~**Pricing**~~	$P_{t+\tau} \equiv P(\tilde{\mathbf{X}}, \mathcal{I}_t)$	$\Longleftrightarrow$	$\boxed{\mathcal{P}} \quad \mathbf{p}_c$
Optimization	$\mathbf{w}^* \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \{\mathcal{S}(\mathbf{w}; \tilde{f}^c_{\mathbf{X}})\}$		

Attilio Meucci - *Fully Flexible Views…* - implementation

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Posterior	$\widetilde{f}_{\mathbf{X}} \equiv \underset{f\in\mathbb{V}}{\operatorname{argmin}}\{\mathcal{E}(f, f_{\mathbf{X}})\}$	$\Longleftrightarrow$	$\mathcal{X}$ $\widetilde{\mathbf{p}} \equiv \underset{\underline{\mathbf{a}}\leq\mathbf{A}\mathbf{f}\leq\overline{\mathbf{a}}}{\operatorname{argmin}}\{\mathcal{E}(\mathbf{f}, \mathbf{p})\}$
Confidence	$\widetilde{f}^{c}_{\mathbf{X}} \equiv (1-c) f_{\mathbf{X}} + c\widetilde{f}_{\mathbf{X}}.$	$\Longleftrightarrow$	$\mathcal{X}$ $\mathbf{p}_c \equiv (1-c)\mathbf{p} + c\widetilde{\mathbf{p}}.$
Pricing	$P_{t+\tau} \equiv P(\widetilde{\mathbf{X}}, \mathcal{I}_t)$	$\Longleftrightarrow$	$\mathcal{P}$ $\mathbf{p}_c$
Optimization	$\mathbf{w}^* \equiv \underset{\mathbf{w}\in\mathcal{C}}{\operatorname{argmax}}\{\mathcal{S}(\mathbf{w}; \widetilde{f}^{c}_{\mathbf{X}})\}$	$\Longleftrightarrow$	…

RELATED LITERATURE

UNIFIED FRAMEWORK: ENTROPY POOLING

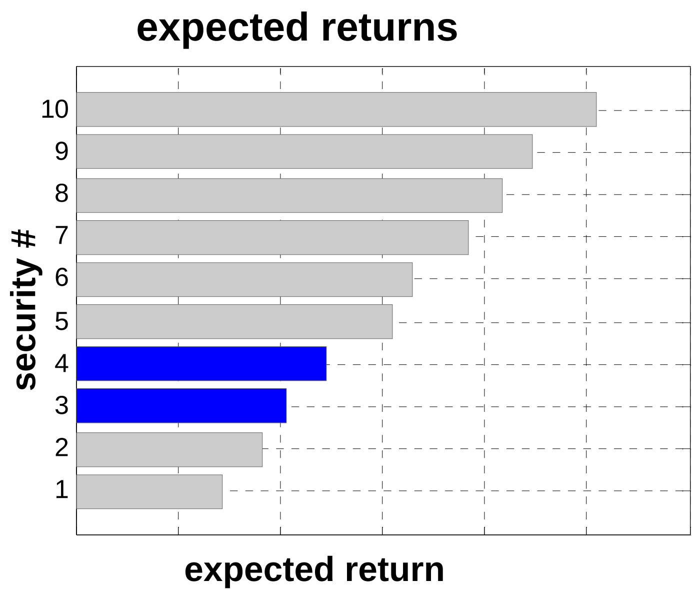
ANALYTICAL SOLUTION

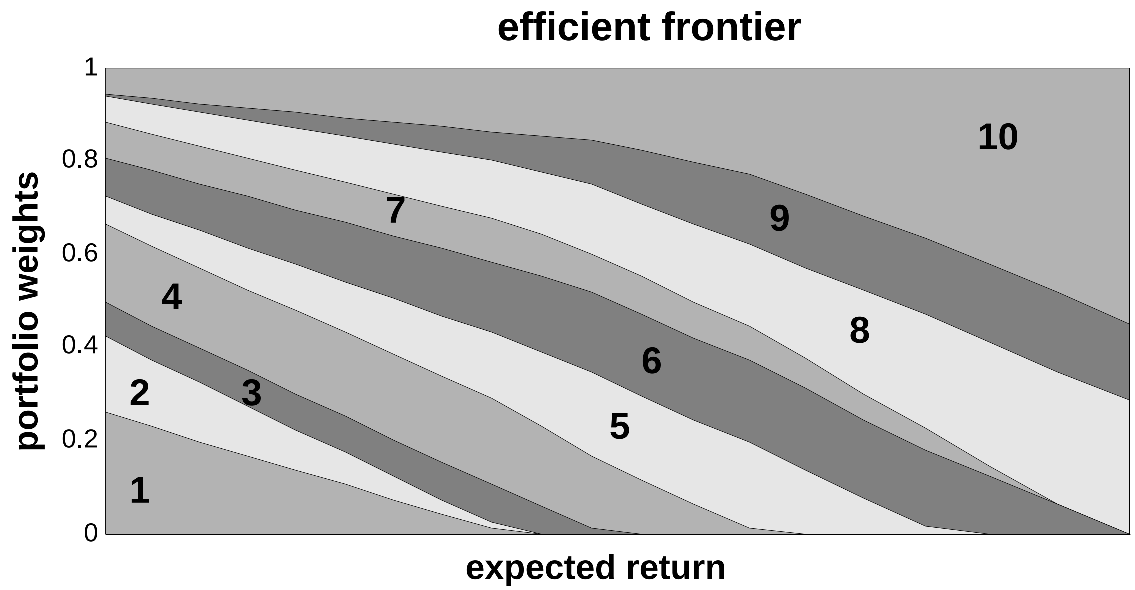
FULLY GENERAL IMPLEMENTATION

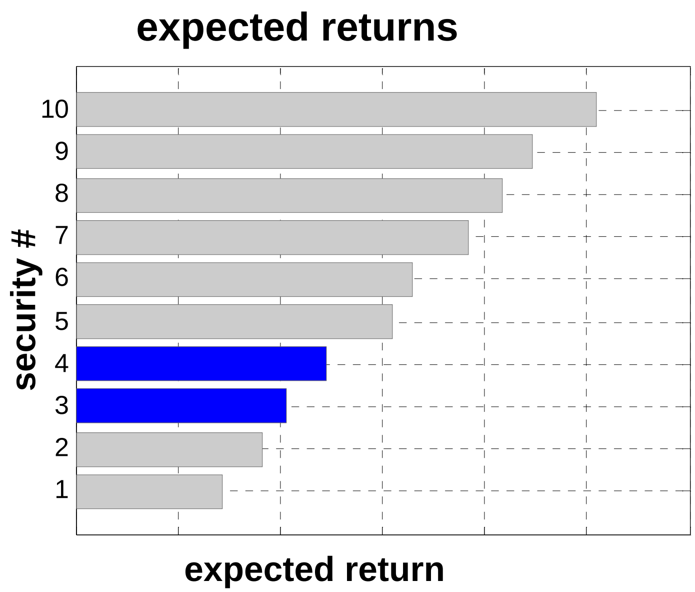
$\boxed{\textbf{CASE STUDIES: RANKING ALLOCATION, OPTION TRADING}}$

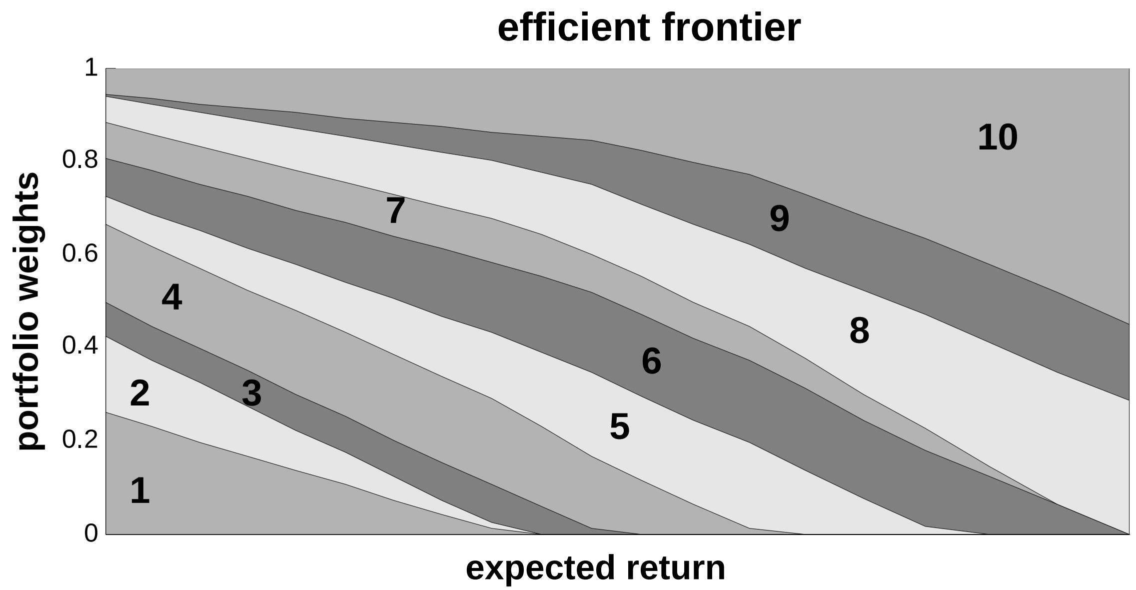
CONCLUSIONS

REFERENCES

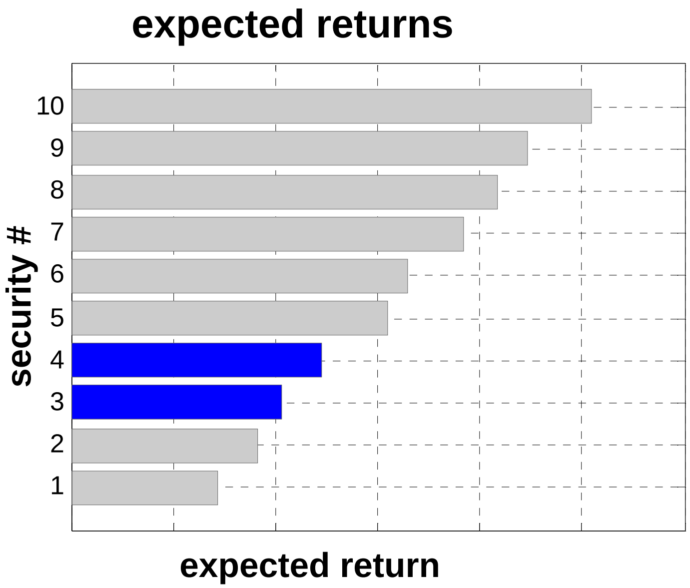

expected returns
10
9
8
7
6
5
4
3
2
1
security #
expected return

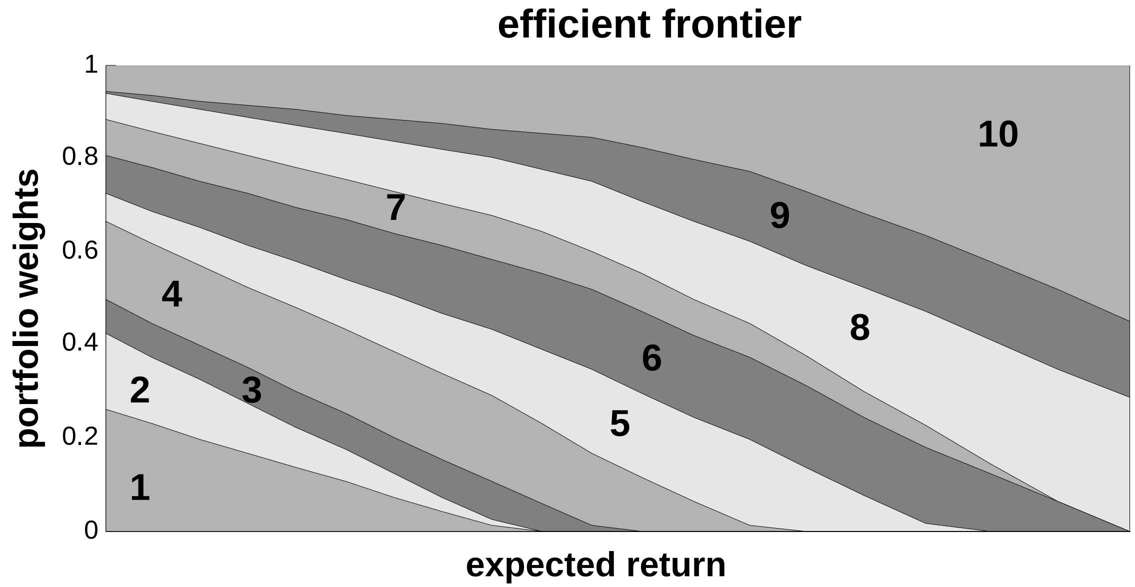

efficient frontier
1
0.8
0.6
0.4
0.2
0
portfolio weights
expected return
10
9
8
7
6
5
4
3
2
1



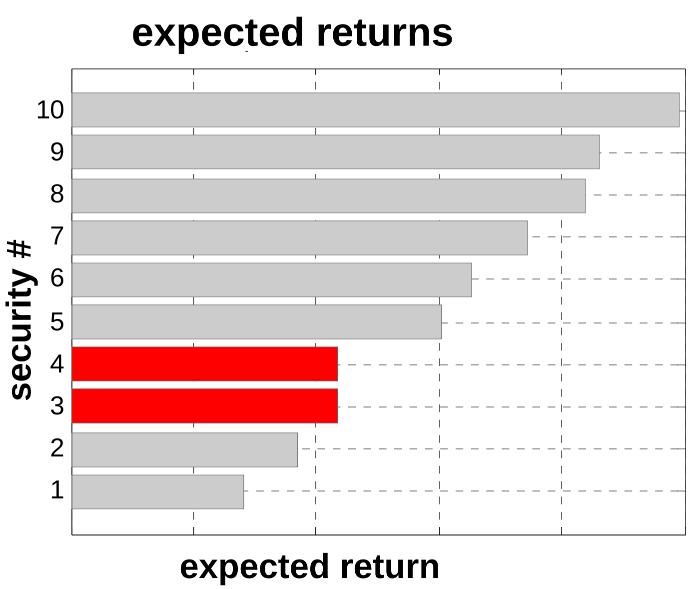


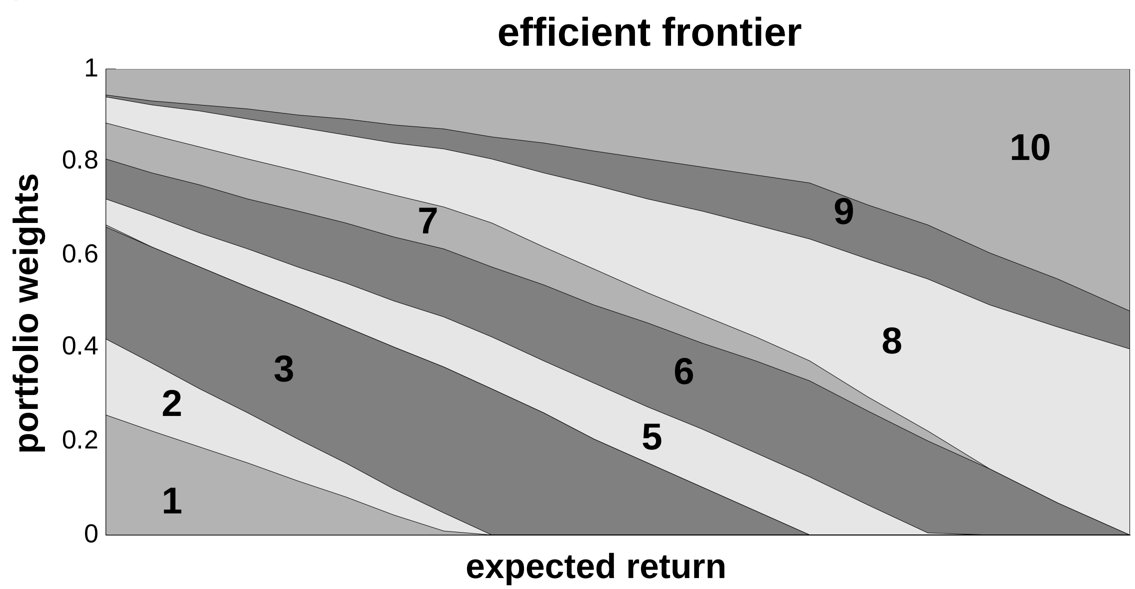
view: $E\left\{R_3\right\} \geq E\left\{R_4\right\}$





view: $E\left\{R_3\right\} \geq E\left\{R_4\right\}$





Black-Scholes formula:
deterministic function of risk into price

$$C_{BS}(y,\sigma;\kappa,T,r) \equiv yF(d_1) - \kappa e^{-rT}F(d_2)$$

$$d_1 \equiv \left(\ln(y/\kappa) + \left(r+\sigma^2/2\right)T\right)/\sigma\sqrt{T}, \qquad d_2 \equiv d_1 - \sigma\sqrt{T};$$

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deterministic function of risk into price

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$$d_1\equiv\left(\ln\left(\boxed{y}/\kappa\right)+\left(r+\boxed{\sigma}^2/2\right)T\right)/\boxed{\sigma}\sqrt{T},\qquad d_2\equiv d_1-\boxed{\sigma}\sqrt{T};$$

$$C_{BS}\left(y,\sigma;\kappa,T,r\right)\equiv yF\left(d_1\right)-\kappa e^{-rT}F\left(d_2\right)$$

$$d_1\equiv\left(\ln\left(y/\kappa\right)+\left(r+\sigma^2/2\right)T\right)/\sigma\sqrt{T},\qquad d_2\equiv d_1-\sigma\sqrt{T};$$

$$h\left(y,\sigma;\kappa,T\right)\equiv\sigma+a\frac{\ln\left(y/\kappa\right)}{\sqrt{T}}+b\left(\frac{\ln\left(y/\kappa\right)}{\sqrt{T}}\right)^2$$

empirical smirk and smile

call option price at horizon $P_{t+\tau} = C_{BS}\left(y_t e^{X_y}, h\left(y_t e^{X_y}, \sigma_t + X_\sigma, \kappa, T-\tau\right); \kappa, T-\tau, r\right)$

$$X_y \equiv \ln\left(y_{t+\tau}/y_t\right)$$

$$X_\sigma \equiv \sigma_{t+\tau} - \sigma_t$$

$$C_{BS}\left(y, \sigma; \kappa, T, r\right) \equiv yF\left(d_1\right) - \kappa e^{-rT} F\left(d_2\right)$$

$$d_1 \equiv \left(\ln\left(y/\kappa\right) + \left(r + \sigma^2/2\right)T\right)/\sigma\sqrt{T}, \qquad d_2 \equiv d_1 - \sigma\sqrt{T};$$

$$h\left(y, \sigma; \kappa, T\right) \equiv \sigma + a\frac{\ln\left(y/\kappa\right)}{\sqrt{T}} + b\left(\frac{\ln\left(y/\kappa\right)}{\sqrt{T}}\right)^2$$

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Portfolio: Microsoft 1 month
Microsoft 2 months
Microsoft 6 months
Yahoo 1 month
Yahoo 2 months
Yahoo 6 months
Google 1 month
Google 2 months
Google 6 months

$$\mathbf{X} \equiv \left(X^M, X^M_{1m}, X^M_{2m}, X^M_{6m}, \ldots, X^G_{6m}, \underbrace{X_{2y}, X_{10y}}\right)'$$

curve change (growth/inflation)
not directly in pricing

call option price at horizon $P_{t+\tau} = C_{BS}\left(y_t e^{X_y}, h\left(y_t e^{X_y}, \sigma_t + X_\sigma, \kappa, T-\tau\right); \kappa, T-\tau, r\right)$

$$X_y \equiv \ln\left(y_{t+\tau}/y_t\right)$$

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$$\mathbf{X} \equiv \left(X^M, X^M_{1m}, X^M_{2m}, X^M_{6m}, \ldots, X^G_{6m}, X_{2y}, X_{10y}\right)' \cancel{\sim \mathrm{N}\left(\boldsymbol{\pi}, \boldsymbol{\Sigma}\right)}$$

call option price at horizon $P_{t+\tau} = C_{BS}\left(y_t e^{X_y}, h\left(y_t e^{X_y}, \sigma_t + X_\sigma, \kappa, T-\tau\right); \kappa, T-\tau, r\right)$

$$X_y \equiv \ln\left(y_{t+\tau}/y_t\right)$$

$$X_\sigma \equiv \sigma_{t+\tau} - \sigma_t$$

$$C_{BS}\left(y,\sigma;\kappa,T,r\right) \equiv yF\left(d_1\right) - \kappa e^{-rT}F\left(d_2\right)$$

$$d_1 \equiv \left(\ln\left(y/\kappa\right) + \left(r+\sigma^2/2\right)T\right)/\sigma\sqrt{T}, \qquad d_2 \equiv d_1 - \sigma\sqrt{T};$$

$$h\left(y,\sigma;\kappa,T\right) \equiv \sigma + a\frac{\ln\left(y/\kappa\right)}{\sqrt{T}} + b\left(\frac{\ln\left(y/\kappa\right)}{\sqrt{T}}\right)^2$$

$$\mathbf{X} \equiv \left(X^M, X^M_{1m}, X^M_{2m}, X^M_{6m}, \ldots, X^G_{6m}, X_{2y}, X_{10y}\right)' \not\sim \mathrm{N}\left(\boldsymbol{\pi}, \boldsymbol{\Sigma}\right)$$

$$\Pi_{\mathbf{w}} \equiv \sum_{i=1}^{I} w_i\left(C_{BS,i}\left(\mathbf{X}, \mathcal{I}_t\right) - C_{i,t}\right)$$

? **profit and loss is highly <u>non-linear</u>, highly <u>non-normal</u>**

call option price at horizon $P_{t+\tau} = C_{BS}\left(y_t e^{X_y}, h\left(y_t e^{X_y}, \sigma_t + X_\sigma, \kappa, T-\tau\right); \kappa, T-\tau, r\right)$

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$$d_1 \equiv \left(\ln\left(y/\kappa\right) + \left(r + \sigma^2/2\right)T\right)/\sigma\sqrt{T}, \qquad d_2 \equiv d_1 - \sigma\sqrt{T};$$

$$h\left(y,\sigma;\kappa,T\right) \equiv \sigma + a\frac{\ln\left(y/\kappa\right)}{\sqrt{T}} + b\left(\frac{\ln\left(y/\kappa\right)}{\sqrt{T}}\right)^2$$

$$\mathbf{X} \equiv \left(X^M, X^M_{1m}, X^M_{2m}, X^M_{6m}, \ldots, X^G_{6m}, X_{2y}, X_{10y}\right)' \nsim \mathrm{N}\left(\boldsymbol{\pi}, \boldsymbol{\Sigma}\right)$$

$$\Pi_{\mathbf{w}} \equiv \sum_{i=1}^{I} w_i \left(C_{BS,i}\left(\mathbf{X}, \mathcal{I}_t\right) - C_{i,t}\right)$$ **?**

Mean-CVaR optimization **?**

$$\mathbf{w}_\lambda \equiv \underset{\underline{\mathbf{b}} \leq \mathbf{B}\mathbf{w} \leq \overline{\mathbf{b}}}{\operatorname{argmax}} \left\{\mathbb{E}\left\{\Pi_{\mathbf{w}}\right\} - \lambda\,\mathrm{CVaR}_\gamma\left\{\Pi_{\mathbf{w}}\right\}\right\}$$

- **long-short delta-neutral**
- **no cash upfront**
- **limit on leverage**

Market distr. $\mathbf{X} \sim f_{\mathbf{X}}$.

Pricing $P_{t+\tau} \equiv P\left(\mathbf{X}, \mathcal{I}_t\right)$?

Optimization $\mathbf{w}^* \equiv \underset{\mathbf{w}\in\mathcal{C}}{\operatorname{argmax}} \left\{\mathcal{S}\left(\mathbf{w}; f_{\mathbf{X}}\right)\right\}$?

call option price at horizon $P_{t+\tau} = C_{BS}\left(y_t e^{X_y}, h\left(y_t e^{X_y}, \sigma_t + X_\sigma, \kappa, T-\tau\right); \kappa, T-\tau, r\right)$

$$X_y \equiv \ln\left(y_{t+\tau}/y_t\right)$$

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$$C_{BS}\left(y, \sigma; \kappa, T, r\right) \equiv y F\left(d_1\right) - \kappa e^{-rT} F\left(d_2\right)$$

$$d_1 \equiv \left(\ln\left(y/\kappa\right) + \left(r + \sigma^2/2\right) T\right) / \sigma\sqrt{T}, \qquad d_2 \equiv d_1 - \sigma\sqrt{T};$$

$$h\left(y, \sigma; \kappa, T\right) \equiv \sigma + a\frac{\ln\left(y/\kappa\right)}{\sqrt{T}} + b\left(\frac{\ln\left(y/\kappa\right)}{\sqrt{T}}\right)^2$$

$$\mathbf{X} \equiv \left(X^M, X^M_{1m}, X^M_{2m}, X^M_{6m}, \ldots, X^G_{6m}, X_{2y}, X_{10y}\right)'$$

simulations

$$\Pi_{\mathbf{w}} \equiv \sum_{i=1}^{I} w_i \left(C_{BS,i}\left(\mathbf{X}, \mathcal{I}_t\right) - C_{i,t}\right) \quad \Leftrightarrow \quad \mathcal{P}_{j,i} \equiv C_{BS,i}\left(\mathcal{X}_{j,\cdot}, \mathcal{I}_t\right) - C_{i,t},$$

$$\mathbf{w}_\lambda \equiv \underset{\underline{\mathbf{b}} \leq \mathbf{B}\mathbf{w} \leq \overline{\mathbf{b}}}{\operatorname{argmax}} \left\{\mathbb{E}\left\{\Pi_{\mathbf{w}}\right\} - \lambda\, \mathrm{CVaR}_\gamma \left\{\Pi_{\mathbf{w}}\right\}\right\}$$

call option price at horizon $P_{t+\tau} = C_{BS}\left(y_t e^{X_y}, h\left(y_t e^{X_y}, \sigma_t + X_\sigma, \kappa, T-\tau\right); \kappa, T-\tau, r\right)$

$$X_y \equiv \ln\left(y_{t+\tau}/y_t\right)$$

$$X_\sigma \equiv \sigma_{t+\tau} - \sigma_t$$

$$C_{BS}\left(y,\sigma;\kappa,T,r\right) \equiv yF\left(d_1\right) - \kappa e^{-rT}F\left(d_2\right)$$

$$d_1 \equiv \left(\ln\left(y/\kappa\right) + \left(r+\sigma^2/2\right)T\right)/\sigma\sqrt{T}, \qquad d_2 \equiv d_1 - \sigma\sqrt{T};$$

$$h\left(y,\sigma;\kappa,T\right) \equiv \sigma + a\frac{\ln\left(y/\kappa\right)}{\sqrt{T}} + b\left(\frac{\ln\left(y/\kappa\right)}{\sqrt{T}}\right)^2$$

$$\mathbf{X} \equiv \left(X^M, X^M_{1m}, X^M_{2m}, X^M_{6m}, \ldots,, X^G_{6m}, X_{2y}, X_{10y}\right)'$$

simulations

$$\Pi_{\mathbf{w}} \equiv \sum_{i=1}^{I} w_i\left(C_{BS,i}\left(\mathbf{X}, \mathcal{I}_t\right) - C_{i,t}\right) \quad \Longleftrightarrow \quad \mathcal{P}_{j,i} \equiv C_{BS,i}\left(\mathcal{X}_{j,\cdot}, \mathcal{I}_t\right) - C_{i,t},$$

$$\mathbf{w}_\lambda \equiv \underset{\underline{\mathbf{b}} \leq \mathbf{Bw} \leq \overline{\mathbf{b}}}{\operatorname{argmax}}\left\{\mathbb{E}\left\{\Pi_{\mathbf{w}}\right\} - \lambda\,\mathrm{CVaR}_\gamma\left\{\Pi_{\mathbf{w}}\right\}\right\} \quad \Longleftrightarrow$$

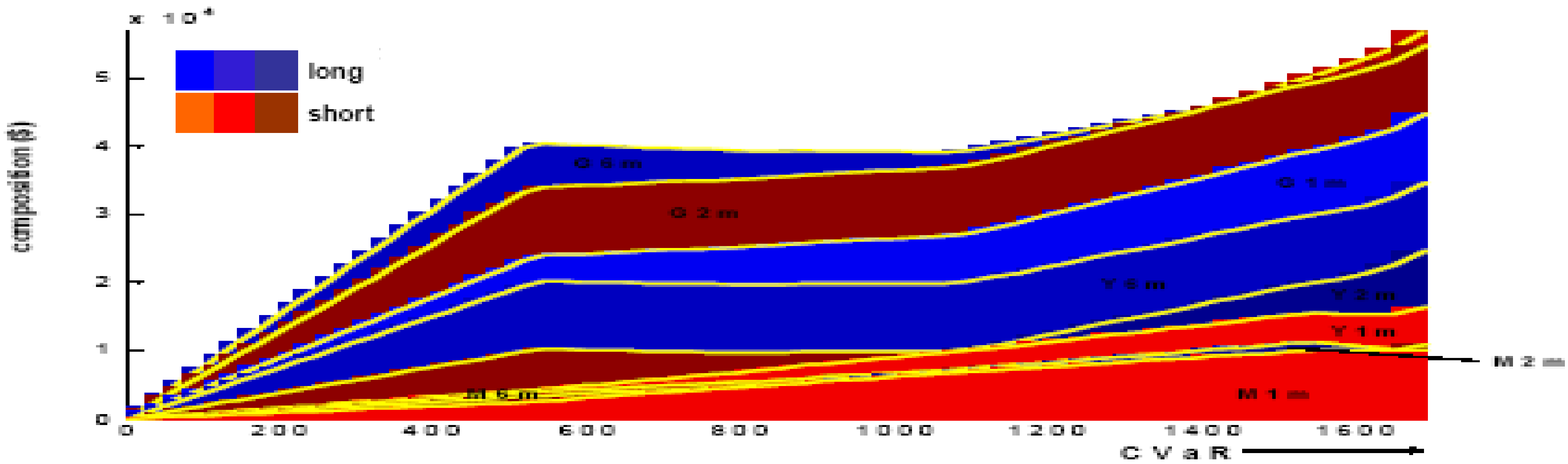
linear programming

Market distr. $\mathbf{X} \sim f_{\mathbf{X}}$. $\Leftrightarrow$ $\mathcal{X}$ $\mathbf{p}$

Pricing $P_{t+\tau} \equiv P(\mathbf{X}, \mathcal{I}_t)$ **?** $\Leftrightarrow$ $\mathcal{P}$, $\mathbf{p}$

Optimization $\mathbf{w}^* \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \{\mathcal{S}(\mathbf{w}; f_{\mathbf{X}})\}$ **?** $\Leftrightarrow$ **linear programming**

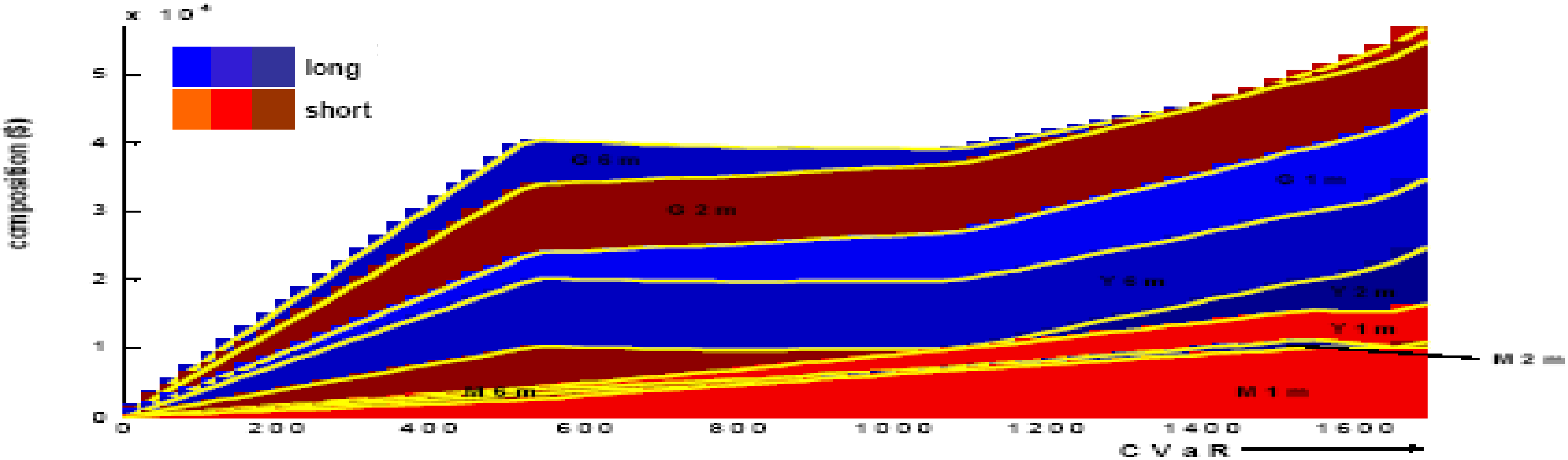
Attilio Meucci - *Fully Flexible Views…* - case study: option trading



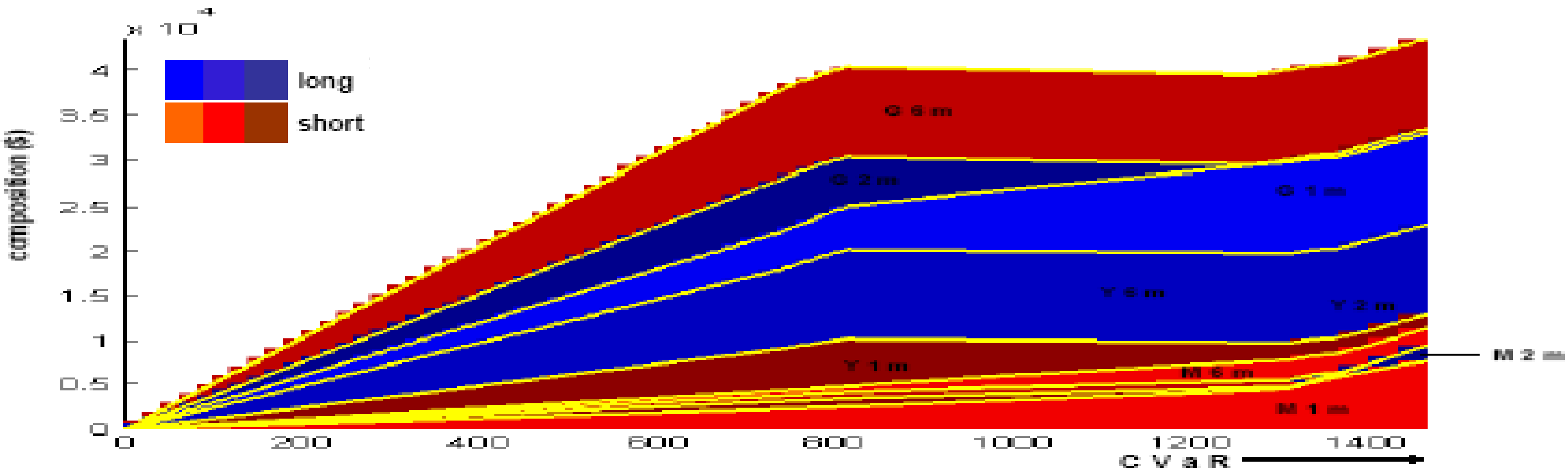
Attilio Meucci - *Fully Flexible Views…* - case study: option trading

Market distr.	$\mathbf{X} \sim f_{\mathbf{X}}$.	$\Longleftrightarrow$	$\mathcal{X}$ $J \times N$ panel $\mathbf{p}$ probabilities $1/J$;
Focus	$\mathbf{V} \equiv \mathbf{g}(\mathbf{X}) \sim f_{\mathbf{V}}$	$\Longleftrightarrow$	$\mathcal{V}_{j,k} \equiv g_k(\mathcal{X}_{j,1}, \ldots, \mathcal{X}_{j,N})$
Views	$\mathbf{V} \sim \widetilde{f}_{\mathbf{V}} \neq f_{\mathbf{V}}$. $\widetilde{m}\{V_k\} \gtreqless \widetilde{\mu}_{\mathbf{v},k}$; $\widetilde{m}\{V_1\} \geq \widetilde{m}\{V_2\} \geq \cdots \geq \widetilde{m}\{V_K\}$ $\widetilde{\sigma}\{V_k\} \gtreqless \varkappa\sigma\{V_k\}$ $\widetilde{\mathbb{C}}\{\mathbf{V}\} \equiv \rho_1\mathbf{I} + \rho_2\mathbb{C}\{\mathbf{V}\} + \rho_3\mathbf{1}\mathbf{1}'$, $\widetilde{Q}_V(u) \gtreqless Q_V(u)$	$\Longleftrightarrow$	$\underline{\mathbf{a}} \leq \mathbf{A}\widetilde{\mathbf{p}} \leq \overline{\mathbf{a}}$.
Posterior	$\widetilde{f}_{\mathbf{X}} \equiv \underset{f \in \mathbb{V}}{\operatorname{argmin}} \{\mathcal{E}(f, f_{\mathbf{X}})\}$	$\Longleftrightarrow$	$\mathcal{X}$ $\widetilde{\mathbf{p}} \equiv \underset{\underline{\mathbf{a}} \leq \mathbf{A}\mathbf{f} \leq \overline{\mathbf{a}}}{\operatorname{argmin}} \{\mathcal{E}(\mathbf{f}, \mathbf{p})\}$
Confidence	$\widetilde{f}^{c}_{\mathbf{X}} \equiv (1-c) f_{\mathbf{X}} + c\widetilde{f}_{\mathbf{X}}$.	$\Longleftrightarrow$	$\mathcal{X}$ $\mathbf{p}_c \equiv (1-c)\mathbf{p} + c\widetilde{\mathbf{p}}$.
Pricing	$P_{t+\tau} \equiv P(\widetilde{\mathbf{X}}, \mathcal{I}_t)$	$\Longleftrightarrow$	$\boxed{\mathcal{P}}$ $\mathbf{p}_c$
Optimization	$\mathbf{w}^* \equiv \underset{\mathbf{w} \in \mathcal{C}}{\operatorname{argmax}} \{\mathcal{S}(\mathbf{w}; \widetilde{f}^{c}_{\mathbf{X}})\}$	$\Longleftrightarrow$	…

Attilio Meucci - *Fully Flexible Views…* - case study: option trading



view: G 6m $\leq$ G 2m



- ✓ **Market represented by generic non-linear risk factors, not just returns**
- ✓ **Market distribution fully general, not just normal**
- ✓ **Market reference model fully general, not just based on equilibrium assumptions**
- ✓ **Views/stress-testing on any function of the market, not just linear combinations**
- ✓ **Views on any feature, not just on expectations: median volatility, correlations, tail-behavior, …**
- ✓ **Views are equalities and inequalities: ranking is possible**
- ✓ **Optimization is fully general, not just mean variance: mean-CVaR, mean-VaR, …**
- ✓ **Repricing is not necessary: complex derivatives handled**

RELATED LITERATURE

UNIFIED FRAMEWORK: ENTROPY POOLING

ANALYTICAL SOLUTION

FULLY GENERAL IMPLEMENTATION

CASE STUDIES: RANKING ALLOCATION, OPTION TRADING

CONCLUSIONS

REFERENCES

Black, F., and R. Litterman, 1990, Asset allocation: combining investor views with market equilibrium, *Goldman Sachs Fixed Income Research*.

	BL
normal market & linear views	✓
scenario analysis	·
correlation stress-test	·
trading desk: non-linear pricing	·
external factors: macro, etc.	·
partial specifications	·
non-normal market	·
multiple users	·
non-linear views	·
trading desk: costly pricing	·
lax constraints: ranking	·

Almgren, R., and N. Chriss, 2006, Optimal portfolios from ordering information, *Journal of Risk* 9, 1–47.

Black, F., and R. Litterman, 1990, Asset allocation: combining investor views with market equilibrium, *Goldman Sachs Fixed Income Research*.

	BL	AC
normal market & linear views	✓	·
scenario analysis	·	·
correlation stress-test	·	·
trading desk: non-linear pricing	·	·
external factors: macro, etc.	·	·
partial specifications	·	·
non-normal market	·	·
multiple users	·	·
non-linear views	·	·
trading desk: costly pricing	·	·
lax constraints: ranking	·	✓

Almgren, R., and N. Chriss, 2006, Optimal portfolios from ordering information, *Journal of Risk* 9, 1–47.

Black, F., and R. Litterman, 1990, Asset allocation: combining investor views with market equilibrium, *Goldman Sachs Fixed Income Research*.

Qian, E., and S. Gorman, 2001, Conditional distribution in portfolio theory, *Financial Analyst Journal* 57, 44–51.

	BL	AC	QG
normal market & linear views	✓	·	✓
scenario analysis	·	·	✓
correlation stress-test	·	·	✓
trading desk: non-linear pricing	·	·	·
external factors: macro, etc.	·	·	·
partial specifications	·	·	·
non-normal market	·	·	·
multiple users	·	·	·
non-linear views	·	·	·
trading desk: costly pricing	·	·	·
lax constraints: ranking	·	✓	·

Almgren, R., and N. Chriss, 2006, Optimal portfolios from ordering information, *Journal of Risk* 9, 1–47.

Black, F., and R. Litterman, 1990, Asset allocation: combining investor views with market equilibrium, *Goldman Sachs Fixed Income Research*.

Pezier, J., 2007, Global portfolio optimization revisited: A least discrimination alternantive to Black-Litterman, *ICMA Centre Discussion Papers in Finance*.

Qian, E., and S. Gorman, 2001, Conditional distribution in portfolio theory, *Financial Analyst Journal* 57, 44–51.

	BL	AC	QG	P
normal market & linear views	✓	·	✓	✓
scenario analysis	·	·	✓	✓
correlation stress-test	·	·	✓	✓
trading desk: non-linear pricing	·	·	·	·
external factors: macro, etc.	·	·	·	·
partial specifications	·	·	·	✓
non-normal market	·	·	·	·
multiple users	·	·	·	·
non-linear views	·	·	·	·
trading desk: costly pricing	·	·	·	·
lax constraints: ranking	·	✓	·	·

Almgren, R., and N. Chriss, 2006, Optimal portfolios from ordering information, *Journal of Risk* 9, 1–47.

Black, F., and R. Litterman, 1990, Asset allocation: combining investor views with market equilibrium, *Goldman Sachs Fixed Income Research*.

Meucci, A.,8b, Enhancing the Black-Litterman and related approaches: Views and stress-test on risk factors, *Working Paper* Available at symmys.com > Reasearch > Working Papers.

Pezier, J., 2007, Global portfolio optimization revisited: A least discrimination alternantive to Black-Litterman, *ICMA Centre Discussion Papers in Finance*.

Qian, E., and S. Gorman, 2001, Conditional distribution in portfolio theory, *Financial Analyst Journal* 57, 44–51.

	BL	AC	QG	P	M
normal market & linear views	✓	·	✓	✓	✓
scenario analysis	·	·	✓	✓	✓
correlation stress-test	·	·	✓	✓	✓
trading desk: non-linear pricing	·	·	·	·	✓
external factors: macro, etc.	·	·	·	·	✓
partial specifications	·	·	·	✓	·
non-normal market	·	·	·	·	·
multiple users	·	·	·	·	·
non-linear views	·	·	·	·	·
trading desk: costly pricing	·	·	·	·	·
lax constraints: ranking	·	✓	·	·	·

Almgren, R., and N. Chriss, 2006, Optimal portfolios from ordering information, *Journal of Risk* 9, 1–47.

Black, F., and R. Litterman, 1990, Asset allocation: combining investor views with market equilibrium, *Goldman Sachs Fixed Income Research*.

Meucci, A., 2006, Beyond Black-Litterman in practice: A five-step recipe to input views on non-normal markets, *Risk* 19, 114–119.

——, 2008b, Enhancing the Black-Litterman and related approaches: Views and stress-test on risk factors, *Working Paper* Available at symmys.com > Reasearch > Working Papers.

Pezier, J., 2007, Global portfolio optimization revisited: A least discrimination alternantive to Black-Litterman, *ICMA Centre Discussion Papers in Finance*.

Qian, E., and S. Gorman, 2001, Conditional distribution in portfolio theory, *Financial Analyst Journal* 57, 44–51.

	BL	AC	QG	P	M	COP
normal market & linear views	✓	·	✓	✓	✓	✓
scenario analysis	·	·	✓	✓	✓	✓
correlation stress-test	·	·	✓	✓	✓	·
trading desk: non-linear pricing	·	·	·	·	✓	✓
external factors: macro, etc.	·	·	·	·	✓	✓
partial specifications	·	·	·	✓	·	·
non-normal market	·	·	·	·	·	✓
multiple users	·	·	·	·	·	✓
non-linear views	·	·	·	·	·	·
trading desk: costly pricing	·	·	·	·	·	·
lax constraints: ranking	·	✓	·	·	·	·

- **Article:**
  Attilio Meucci, "Fully Flexible Views: Theory and Practice"
  ***The Risk Magazine* - October 2008, p 97-102**
  available at www.symmys.com > Research > Working Papers

- **MATLAB examples:**
  www.symmys.com > Teaching > MATLAB

- **This presentation:**
  www.symmys.com > Teaching > Talks

	BL	AC	QG	P	M	COP	EP
normal market & linear views	✓	·	✓	✓	✓	✓	✓
scenario analysis	·	·	✓	✓	✓	✓	✓
correlation stress-test	·	·	✓	✓	✓	·	✓
trading desk: non-linear pricing	·	·	·	·	✓	✓	✓
external factors: macro, etc.	·	·	·	·	✓	✓	✓
partial specifications	·	·	·	✓	·	·	✓
non-normal market	·	·	·	·	·	✓	✓
multiple users	·	·	·	·	·	✓	✓
non-linear views	·	·	·	·	·	·	✓
trading desk: costly pricing	·	·	·	·	·	·	✓
lax constraints: ranking	·	✓	·	·	·	·	✓