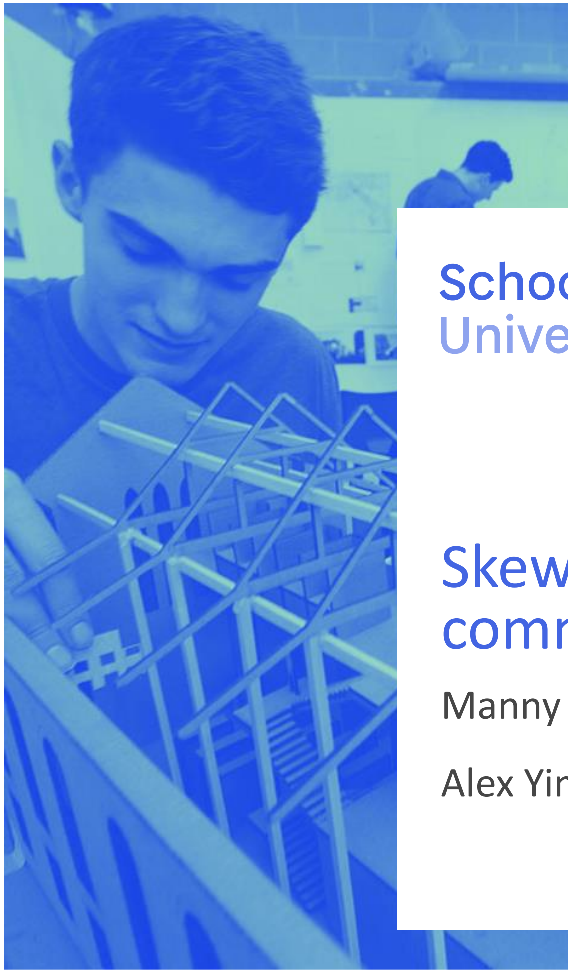

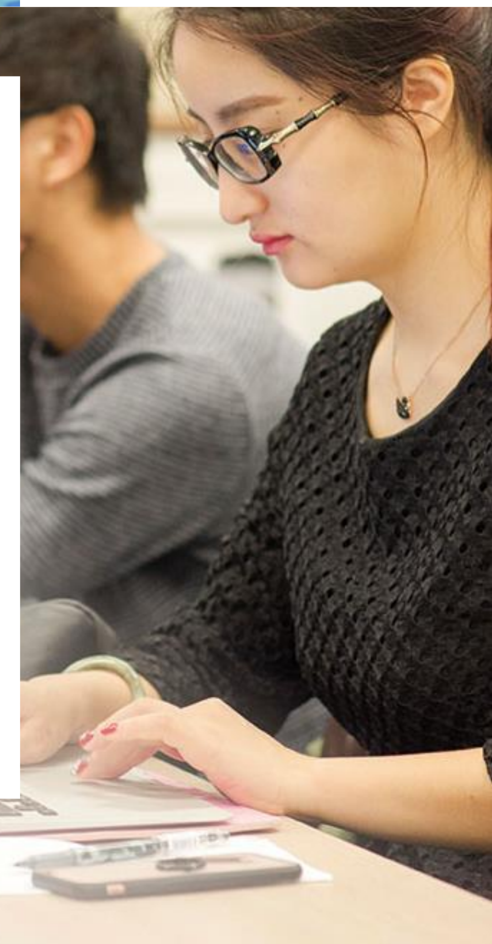

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Skew preference in energy commodity option design

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Outline

- Background & objectives
- Skew, tail risk management, & preferences
- Methodology
- Main results
- Conclusions

Option design

- Pay-off profiles of option buyer or seller (the risks they bear) skewed & asymmetric by design

- Poorly designed option could result in inadequate or excessive risk mitigation
  - Arbitrarily high call strike
  - Capriciously large portfolio weight of fixed-for-floating swap

- A formidable task, even under benign circumstances!

Setting of electric utility regulation

- Fiduciary duty to seek prudent programme for fuel cost hedging

- Yet multiple stakeholders (with potentially diverse skew preferences) influence configuration of hedging programme
  - Under adversarial process, features of hedging programme (e.g. structure of option, weight in portfolio, budget for premiums, etc.) subject to detailed scrutiny during discovery, negotiation, or litigation
  - Under regulatory incentive system, penalties or rewards themselves (perhaps unwittingly) imply preference for specific portfolio distribution

Objectives

- Develop optimisation model for determining mix & structure of energy commodity options, given alternative levels of skew preference & option premium budgets
- Implement calibrations & simulations of scenarios pertaining to skew preference, option premium budgets, & representation of California regulatory incentive system
- Assess economic consequences of mischaracterising concept of skew in design of natural gas options

On the matter of skew

- Variance analysis
  - Extremely high or extremely low returns equally undesirable
  - Sacrifices too much expected return in eliminating both extremes

- Semi-variance analysis
  - Concentrates on reducing losses
  - Selects portfolio with greatest skewness to the right or least skewness to the left

(Markowitz 1959)

Tail risk & positive skew

- High probability of extreme event in positive direction preferred to high probability of extreme event in negative direction
- Some expected return could be traded for decrease in prospect of suffering large reduction in wealth
- Defining risk in terms of negative returns (i.e. distinguishing between “good” & “bad” variance)
- Increase positive skewness through various means, such as options

(Estrada 2008, Konno et al 1998, Tehranian 1980, Harvey and Siddique 2000, Athayde and Flores 2004, Harvey et al 2010, Chiu 2010, Tsiang 1972, Xiong and Idzorek 2011, Mhiri and Prigent 2010, Genest et al 2016)

Systematic approach to risk management

- Price (how much to pay for hedging), probability (how to assess likelihood), & preference (how much risk to bear & how much to hedge)

- Preference likely most important but least understood, & matters greatly indeed

- Almost impossible to ascertain utility function of decision maker (worse if group of decision makers with different utility functions)

- Identifying “better” optimiser “largely meaningless” (what matters is perception of appropriate risk measure)

(Konno et al 1998, Garcia et al 1994, Lo 1999, Dentcheva and Ruszczynski 2003, Estrada 2008, Servaes et al 2009)

Prudence standard applied to natural gas hedging

- Financial hedging, if done properly, offers protection from excessive price volatility

- Regulator has to evaluate utility's proposed hedging programme & determine whether or not it was executed prudently

- Insufficient hedging could expose customers to risk of high prices, but excessive hedging could be costly relative to benefits

- Regulator has to find balance between providing utility as much predictability as possible & testing whether or not any hedging costs imprudent

(Beecher 2008, Lazar 2011, Littlechild 2012, McDermott 2012)

Action or inaction, deliberate or otherwise, implies preference for one perspective or another

- Implementation of hedging programme depends on customer risk preferences for cost, terms, & desired volatility protection

- Neither utilities nor regulators understand price which customers willing to pay in order to avoid extremely high natural gas bills during winter months

- Absence of empirical analysis of ratepayer risk preferences

- Not hedging, a special case of speculation

(CPUC 2010, Costello 2011, Graves 2013, Ehrbar 2016, Makholm et al 2006)

Methodology

- Calibrate model of natural gas forward price
- Conduct Monte Carlo simulation at certain transaction & delivery periods
- Formulate & solve optimisation model with five choice variables
  - Adder call option
  - Subtractor of put option
  - Weights for three instruments (open position, collar, & fixed-for-floating swap)

(Roques et al 2008, Cheong et al 2007, Liu and Wu 2007, Kleindorfer and Li 2005, Woo et al 2006, Woo et al 2004, Oum and Oren 2010, Vehviläinen and Keppo 2003, Bessembinder and Lemmon 2002, Siddiqui 2003, Brown and Toft 2001, Gay et al 2003, Garcia et al 1994, Gerner and Ronn 2013, Oum et al 2007)

Modelling

- Objective function is three-moment utility function
  - Specifying hedged portfolio for cost
  - Incorporating variance & skew preferences represented as combinations of 1/0 coefficients (i.e. allowing their effects to be “switched” on or off)

- A key constraint: collar premiums budget exogenously specified

- Investigate various scenarios
  - Skew preference
  - Option premium budgets
  - Representation of California regulatory incentive system

Forward price at transaction *t* for delivery *T*

$F_{t,T} = F_{0,T} exp\left(Z\sigma_T\sqrt{T} - \frac{1}{2}\sigma_T^2 T\right)$ in which

$F_{0,T}$ is the initial forward price

σ_T is implied volatility

$Z \sim N(0,1)$ is a standard normal random variable

future spot price S_T is approximated as $F_{T,T}$, which is the forward price at transaction and delivery period T, and the forward price at Monte Carlo simulation $k = 1 \ldots K$ is expressed as $F_{t,T}^k$

Endogenous option premium & effective price

The adder x_T^a and the subtractor x_T^s, respectively, determine not only the call and put strikes endogenously creating the collar, but also the call premium $P_{t,T}^c$ and put premium $P_{t,T}^p$, both of which endogenously define the collar net premium.

The fair value of the call or put premium is estimated as the discounted average option value realised across all simulations.

At simulation k and delivery period T, the effective price $I_T^{i,k}$ depends on instrument i.

$$I_T^{i,k} = \begin{cases} S_T^k = F_{T,T}^k \ \forall \ i = 1 \\ min\left(F_{T,T}^k, F_{0,T} + x_T^a\right) \forall \ i = 2 \\ max\left(F_{T,T}^k, F_{0,T} - x_T^s\right) \forall \ i = 2 \\ F_{0,T} \ \forall \ i = 3 \end{cases} \tag{1}$$

indicating the effective price set by instrument i at simulation k.

Optimisation model

Incorporate λ, representing risk aversion pertaining to variance, and γ, representing skewness preference, as 1/0 coefficients allowing their effects to be "switched" on or off in different combinations. Bringing the modelling components together, we have

$$Max_{x_T^a, x_T^s, w_T^i} \left(-M_T - \frac{\lambda}{2} A_T^2 - \frac{\gamma}{6} S_T \right) \tag{2}$$

subject to the following constraints:

$$\frac{\left(P_{t,T}^c - P_{t,T}^p\right)\left(w_T^2\right)}{F_{0,T}} = b \tag{3}$$

$$\sum_i w_T^i = 1 \tag{4}$$

$$\left(F_{0,T} - x_T^s\right) \geq 0.01 \tag{5}$$

$$x_T^a, x_T^s, w_T^i, \left(P_{t,T}^c - P_{t,T}^p\right) \geq 0. \tag{6}$$

Control of "bad variance"

- Introduction of skew preference leads to control of high or reduction of low
- Variance concentrated in favourable extreme
- Achieved through granular modifications to mix or structure of instruments

						Collar				
			Mix			Call		Put		Net
	λ	γ	Swap	Collar	Open	Strike	Premium	Strike	Premium	Premium
A	-	-	0%	43%	57%	3.5142	0.1726	2.0500	0.0337	0.1389
B	-	1.00	82%	18%	0%	3.0000	0.3384	0.6582	-	0.3384
C	1.00	-	0%	100%	0%	3.0000	0.3384	2.8785	0.2784	0.0600
D	1.00	1.00	82%	18%	0%	3.0000	0.3384	0.4180	-	0.3384

Economic damage from tail risk mismanagement

- Consider annual natural gas expenditure of $1B (reasonable for small- or medium-sized electric utility)
  - If forward price $3/MMBtu, annual volume approximately 333,333,333 MMBtu
  - At 2% budget, option premium expense $20M

- Difference between p01 of Portfolio C, $2.8785/MMBtu, & that of Portfolio D, $2.7238/MMBtu, about $0.1547/MMBtu

	λ	γ	p95	p50	Average	p01	V	S
A	-	-	4.1796	2.8680	2.9353	1.7048	0.5434	0.4081
B	-	1.00	3.0000	2.9766	2.9367	2.7238	0.0061	(1.0505)
C	1.00	-	3.0000	2.8785	2.9353	2.8785	0.0035	0.1304
D	1.00	1.00	3.0000	2.9766	2.9367	2.7238	0.0061	(1.0505)

- Harm associated with missed opportunity for enjoyment of low prices could be as much as $52M (more than twice option premium expense!)

Doubling the budget from 2% to 4%

- Reduces p01 & increases portfolio weight of collar
- For a given variance preference, higher budget increases ability to pay for pricey collars required to secure lower p01
- But higher budget *per se* may not be as important as properly designing structure or mix of options (as we have seen above)
- Crucial for regulatory stakeholders, using a common language, to understand, measure, & articulate economic implications of their risk preferences

GCIM applied to Southern California Gas Company & San Diego Gas & Electric Company

- Procurement performance measured against tolerance band
  - Upper limit, two percentage points above benchmark
  - Lower limit, one percentage point below it

- Incentives
  - If actual purchase cost is within tolerance, all gains or losses accrue to ratepayers
  - If it exceeds upper limit, burden of excess costs shared evenly between investors & ratepayers
  - If it falls between lower limit & five percentage points below benchmark, 25% of savings granted as reward to investors, 75% to ratepayers
  - If it falls below benchmark by more than five percentage points, 10% of savings granted as reward to shareholders, 90% to ratepayers

- Maximum total investor reward 1.5% of benchmark

(CPUC 2017)

Under a representation of GCIM, we model the payoff as

$$max\{-E + R_1 + R_2, (0.0150)(B)\} \tag{7}$$

in which B is the benchmark,

$$E = \begin{cases} \{M_T - B - (0.0200)(B)\}\{0.5000\} & \frac{M_T - B}{B} > 0.0200 \\ 0 & otherwise \end{cases} \tag{8}$$

$$R_1 = \begin{cases} \{B - M_T - (0.0100)(B)\}\{0.2500\} & 0.0100 \leq \frac{B - M_T}{B} \leq 0.0500 \\ 0 & otherwise \end{cases} \tag{9}$$

$$R_2 = \begin{cases} \{B - M_T - (0.0500)(B)\}\{0.1000\} & 0.0500 < \frac{B - M_T}{B} \\ 0 & otherwise \end{cases} \tag{10}$$

and M_T represents an estimate of actual purchase cost

Condition (7) is the payoff function, including the cap on net reward.

Condition (8) is the penalty function, and conditions (9) and (10) together constitute the reward function.

The adjusted optimisation model, but with the same choice variables, is to maximise (7) subject to constraints (3) to (6).

Considerable divergence between portfolio distributions of λ/γ & GCIM

- Results look consistent with penalties &rewards embedded in GCIM
  - Portfolio I has higher p95, variance, & skew than Portfolio D (skew of Portfolio I positive, but that of Portfolio D negative)
  - Portfolio I has lower p01 than Portfolio D (good job!)

- Yet exposure of ratepayers to “bad variance” large
  - Preferences implied in Portfolio I enhanced prospects for enjoyment of low price realisations, but elevated risk of high price realisations, relative to preferences articulated in Portfolio D
  - CDF of Portfolio I looks similar to that of open portfolio (Figure 3) & is evidently different to those of Portfolios D or H (Figures 1 & 2)

Figure 1 CDF, open & Portfolios A to D (2% budget)

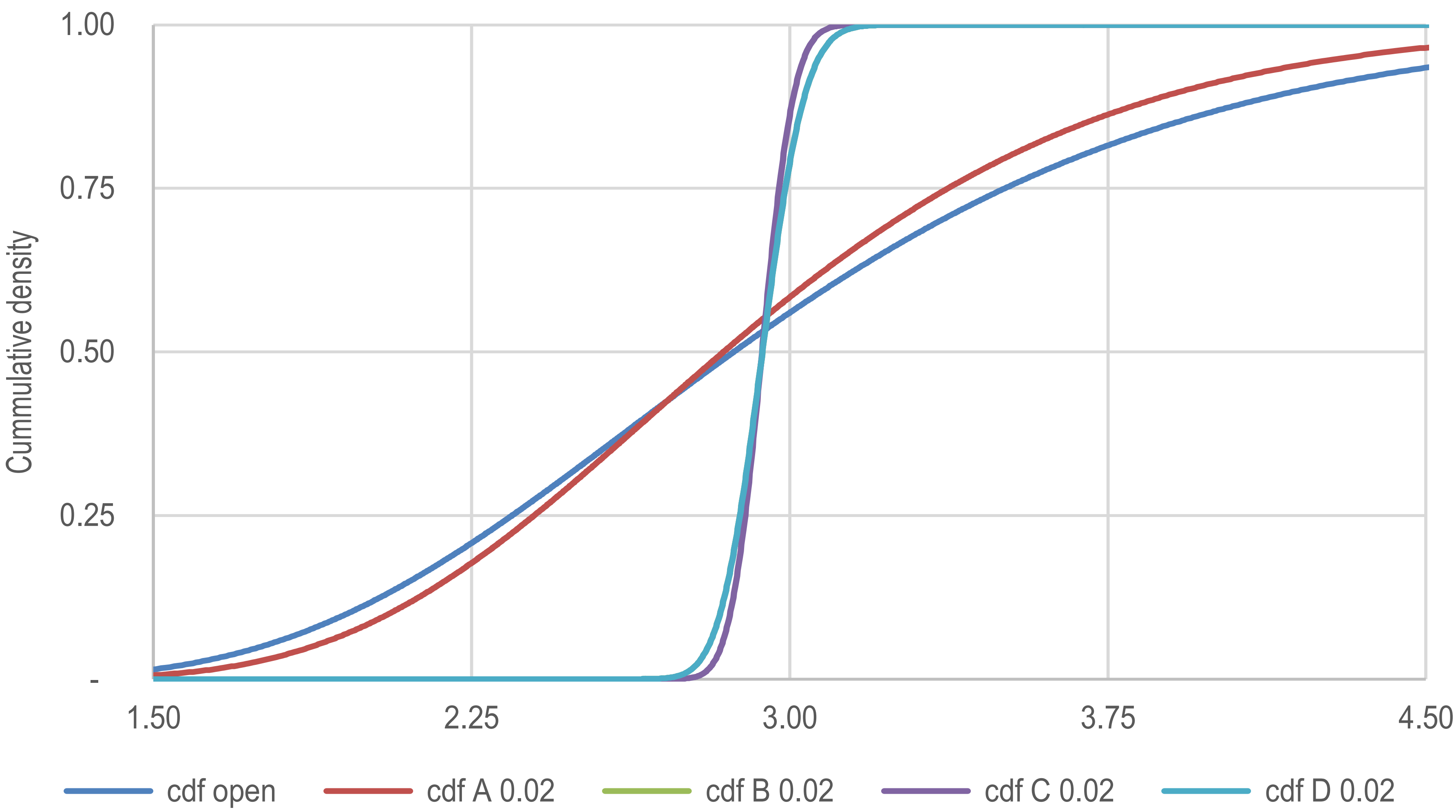


Figure 2 CDF, open & Portfolios E to H (4% budget)

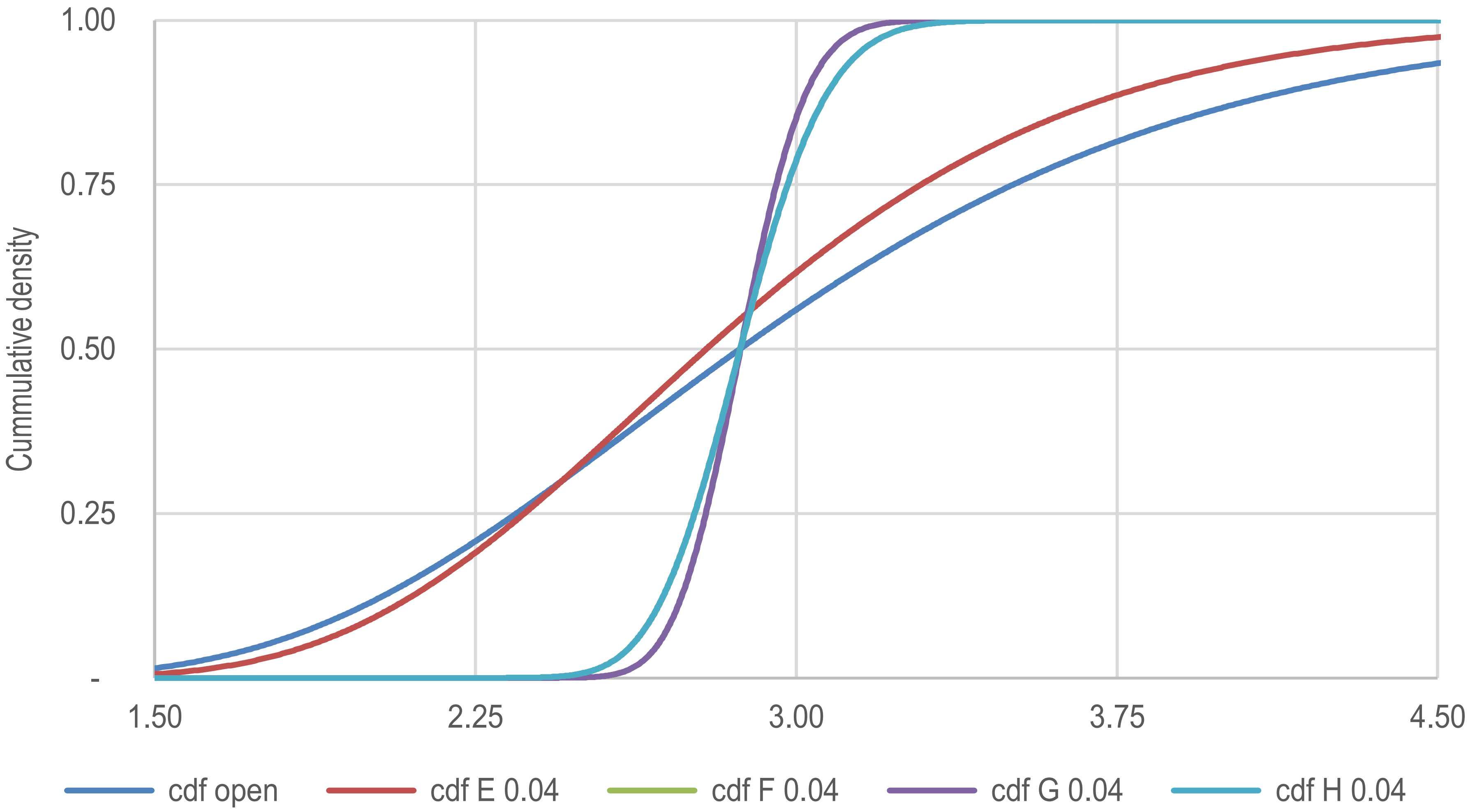
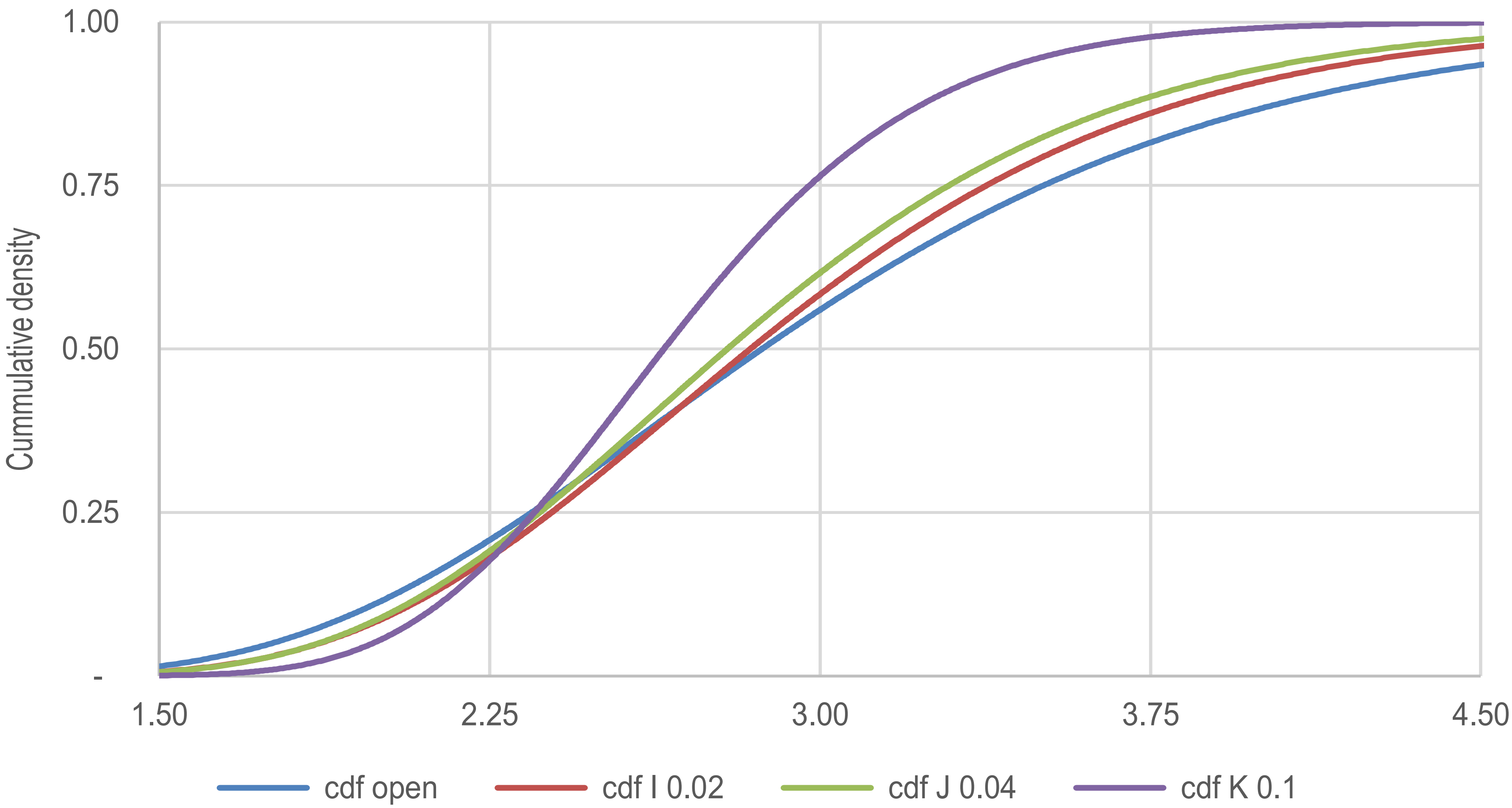


Figure 3 CDF, open & Portfolios I to K



Conclusions

- Under adversarial process or incentive system, regulatory stakeholders could influence design of ostensibly prudent hedging programme

- Concept of skew preference, endogenous mix or structure of financial instruments, & use of option premium budgets, together within unified modelling framework, assist regulatory stakeholders in evaluating economic consequences of alternative portfolio distributions

- Skew preference not only alters portfolio distribution in favourable manner, but also controls "bad" variance

- Proper design of mix or structure of options may be more crucial than large budget

- Portfolio distribution arising from articulated preferences fundamentally different to that arising from preferences implied by representation of GCIM

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