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Evaluating marketing investment projects in the mining industry

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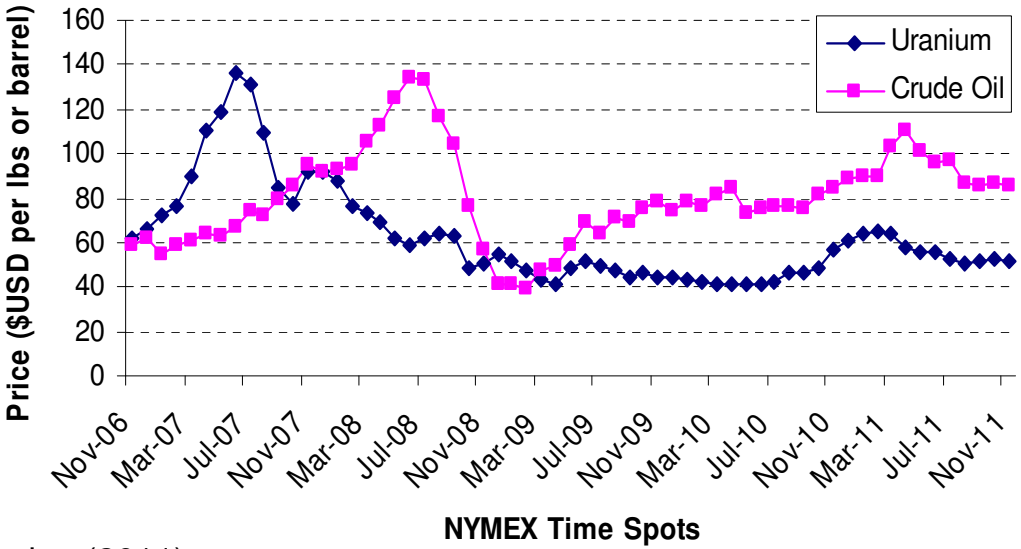
Abstract

- Case study of investment evaluation at Paladin: multinational uranium mine in WA, Australia
- Uranium U-235 expensive, difficult to store and transport, need advanced logistics scheduling
- Nuclear energy cleaner & more efficient than coal, oil (wind, hydro, solar not as cost-effective)
- Reactors: US=104+28, France=58+1, Japan=51+5, USSR=32+30, SKorea=21, India=20+40
- Global recession reduced U-235, all exports
- Australia = 0 nuclear, U-235 > xrays, exports
- U-235, crude oil, energy prices unpredictable
- Market volatile, investment models unreliable
- Long-term logistic plan: U-235 $52 v. $140/lb
- Survey clients, nonlinear program scenarios
- Goal: mean demand ≥ 230,000 lbs, 34 clients
- Problem: average demand forecast too risky.



Sources: American Petroleum Institute (2011), NYMEX (2011), Paladin (2011), Reuters (2011), World Nuclear Association (2011).

Introduction: Business Problem

- **Interesting uranium product characteristics**
  - U235 is refined & enriched into a silvery white, radioactive metal
  - Uranium-235 used in nuclear power, weapons, xrays, neon signs
  - Powerful nuclear reaction created via bombardment by neutrons
    - Power? 15 lb uranium-235 = atomic bomb = 90,000 tons coal energy
  - U235 #2 dense metal, radioactive, not as strong as Plutonium #1
  - Refined uranium $52 / lb, (NYMEX, 2011, November 30) [50x]
  - Plutonium $2,540,115 / lb; $5,600/g (NYMEX, 2011); 1lb=453.592g
  - Oil $0.29/lb [$85.53/barrel]; Texas crude oil density = 873kg/m^2
    - 1 barrel crude oil = 42 gallons; 1 gal = 7lbs X 42 gallons = 294 lbs
- **Marketing in mining = logistics + supply chain management**
  - Marketing function is negligible, focused on quality+compliance & SCM
  - U235 reacts with most nonmetallic elements and their compounds
  - Reacts if increase or decrease in temperature = special logistics (it can react with cold water, air, uranium metal becomes coated with uranium oxide; also it is radioactive = dangerous to humans)
  - Trade agreements & international law requires import/export control
  - Mining company surveys clients for key factors: demand & schedule
  - Uses linear programming to create optimal annual production plan
  - Best price: delivery timeframe 3-24 months, quantity ≥100,000lbs
  - Two projects A & C feasible; need evaluation, can't sell U-235 twice

Background: Uranium vs. crude oil 5-year price level

Month	U-235 $/lb	Oil $/barrel	U-235:oil
Nov-06	61.44	59.13	103.91%
Dec-06	66.57	62	107.37%
Jan-07	72	54.24	132.74%
Feb-07	76.25	59.25	128.69%
Mar-07	89.44	60.6	147.59%
Apr-07	110.43	63.94	172.71%
May-07	119.11	63.45	187.72%
Jun-07	136.22	67.49	201.84%
Jul-07	131.5	74.14	177.37%
Aug-07	109.6	72.38	151.42%
Sep-07	85	79.91	106.37%
Oct-07	77.5	85.9	90.22%
Nov-07	92	94.76	97.09%
Dec-07	91.8	91.36	100.48%
Jan-08	87.56	92.98	94.17%
Feb-08	76	95.38	79.68%
Mar-08	73.71	105.47	69.89%
Apr-08	69.44	112.62	61.66%
May-08	61.67	125.37	49.19%
Jun-08	59	133.93	44.05%
Jul-08	61.84	133.38	46.36%
Aug-08	64.5	116.64	55.30%
Sep-08	63	103.94	60.61%
Oct-08	48.6	76.61	63.44%
Nov-08	50.5	57.29	88.15%
Dec-08	54.33	41.44	131.11%
Jan-09	51.44	41.74	123.24%
Feb-09	47	39.15	120.05%
Mar-09	43.38	47.98	90.41%
Apr-09	41.72	49.81	83.76%
May-09	48.56	59.12	82.14%
Jun-09	51.5	69.58	74.02%
Jul-09	49.7	64.14	77.49%
Aug-09	47.19	71.06	66.41%
Sep-09	44.28	69.44	63.77%
Oct-09	46.11	75.77	60.86%
Nov-09	44.75	78	57.37%
Dec-09	44.44	74.49	59.66%
Jan-10	43.83	78.34	55.95%
Feb-10	42.1	76.3	55.18%
Mar-10	40.91	81.25	50.35%
Apr-10	41.33	84.5	48.91%
May-10	41.3	73.74	56.01%
Jun-10	40.78	75.35	54.12%
Jul-10	41.94	76.16	55.07%
Aug-10	46.06	76.6	60.13%
Sep-10	46.67	75.26	62.01%
Oct-10	48.83	81.9	59.62%
Nov-10	57.16	84.19	67.89%
Dec-10	60.63	89.22	67.96%

Ratio: >100% means uranium costs more per pound than crude oil per barrel; June 2007 U-235/lb 2 times price of West Texas sweet crude oil / barrel

Part 2: Month	U-235 $/lb	Oil $/barrel	U-235:oil
Jan-10	43.83	78.34	55.95%
Feb-10	42.1	76.3	55.18%
Mar-10	40.91	81.25	50.35%
Apr-10	41.33	84.5	48.91%
May-10	41.3	73.74	56.01%
Jun-10	40.78	75.35	54.12%
Jul-10	41.94	76.16	55.07%
Aug-10	46.06	76.6	60.13%
Sep-10	46.67	75.26	62.01%
Oct-10	48.83	81.9	59.62%
Nov-10	57.16	84.19	67.89%
Dec-10	60.63	89.22	67.96%
Jan-11	63.88	89.51	71.37%
Feb-11	65	89.37	72.73%
Mar-11	63.5	102.92	61.70%
Apr-11	57.82	110.04	52.54%
May-11	56.06	101.25	55.37%
Jun-11	55.4	96.25	57.56%
Jul-11	52.79	97.19	54.32%
Aug-11	50.7	86.33	58.73%
Sep-11	51.98	85.62	60.71%
Oct-11	52.34	86.41	60.57%
Nov-11	51.75	85.53	60.51%
Statistics	**U-235 $/lb**	**Oil $/barr**	**U235:Oil Index**
Mean	62.653	80.444	83.08%
SD	22.497	20.963	37.82%
Median	55.400	78.000	66.41%
CV	0.359	0.261	45.53%
Skew	1.636	0.418	153.76%
Kurtosis	2.407	0.326	171.31%
N	61	61	61
Spearman correlation		0.03178923	

Average uranium price $63/lb over 5 years vs. oil $80/barrel; standard deviation (beta risk) is similar but coefficient of variation higher at 36% U-235 v 26% oil (this means uranium market prices are more volatile); no correlation in price levels.

Methods

- Single case study with sequenced mixed methods (Creswell, 2009)
- Historical data gathering for price and market data with descriptive statistics
- Statistical forecasting (linear + quadratic) to predict future demand & prices
- Surveys with clients in 34 countries to establish demand vs. planned schedule
- Linear and nonlinear goal programming to plan production scenarios
- Descriptive statistics and probability distribution analysis to evaluate models
- Research problem: which uranium investment project is less risky?
- Hypothesis: U-235 mean client demand ≥ 230,000 lbs (95% significance level)

Case study participant

- Case study: Paladin Energy Ltd. 502 Hay Street, Subiaco (Perth) WA, 6008 Australia http://www.paladinenergy.com.au/
- Co-owner: Langer Heinrich Uranium Pty. Republic of Namibia (Africa); and Paladin (Africa) Ltd , Malawi (Africa)
- *Paladin* name refers to German King Charlemagne's knights (742 – 814 AD)
- Competition: AREVA, Bannerman Res., Extract Res., Fission Energy Corp., Hathor Exploration, Mantra Res., Mawson Res, Rio Tinto, Rockgate, UEX, Uranerz En., Uranium En., Uranium 1.
- Rio > Hathor; UEX-Cameco venture
- Biggest sources: Cigar Lake Athabasca, Perth WA, PRB Wyoming; 28% 4-yr increase: Kazakhstan (WEurope) & Namibia (Africa)

Methods: Hypothesis testing refresher

- Statistically, the t-test "tails" refers to the tail end of the probability distribution as if you can mentally picture the bell curve, with negative pointing left, and positive right.
- The 'probability' means the likelihood of the sample mean from the estimate you just measured would appear in other similar samples from the actual underlying population, 95 times out of 100 - assuming you used the 95% confidence level in the test configuration (default).
- In terms of the 'tail' in t-tests, when testing two samples or two comparative inventory databases as in this case, you would set up an hypothesis that the means of one sample are significantly different, or that one is smaller or larger than the other.
- In statistics we start with assuming that there is no difference which is known as the null (default) hypothesis.
- From that you layout the actual hypotheses in more scientific terms:

Null hypothesis: M1 => M2 Alternate hypothesis: M1 <= M2 (1-tailed)

OR

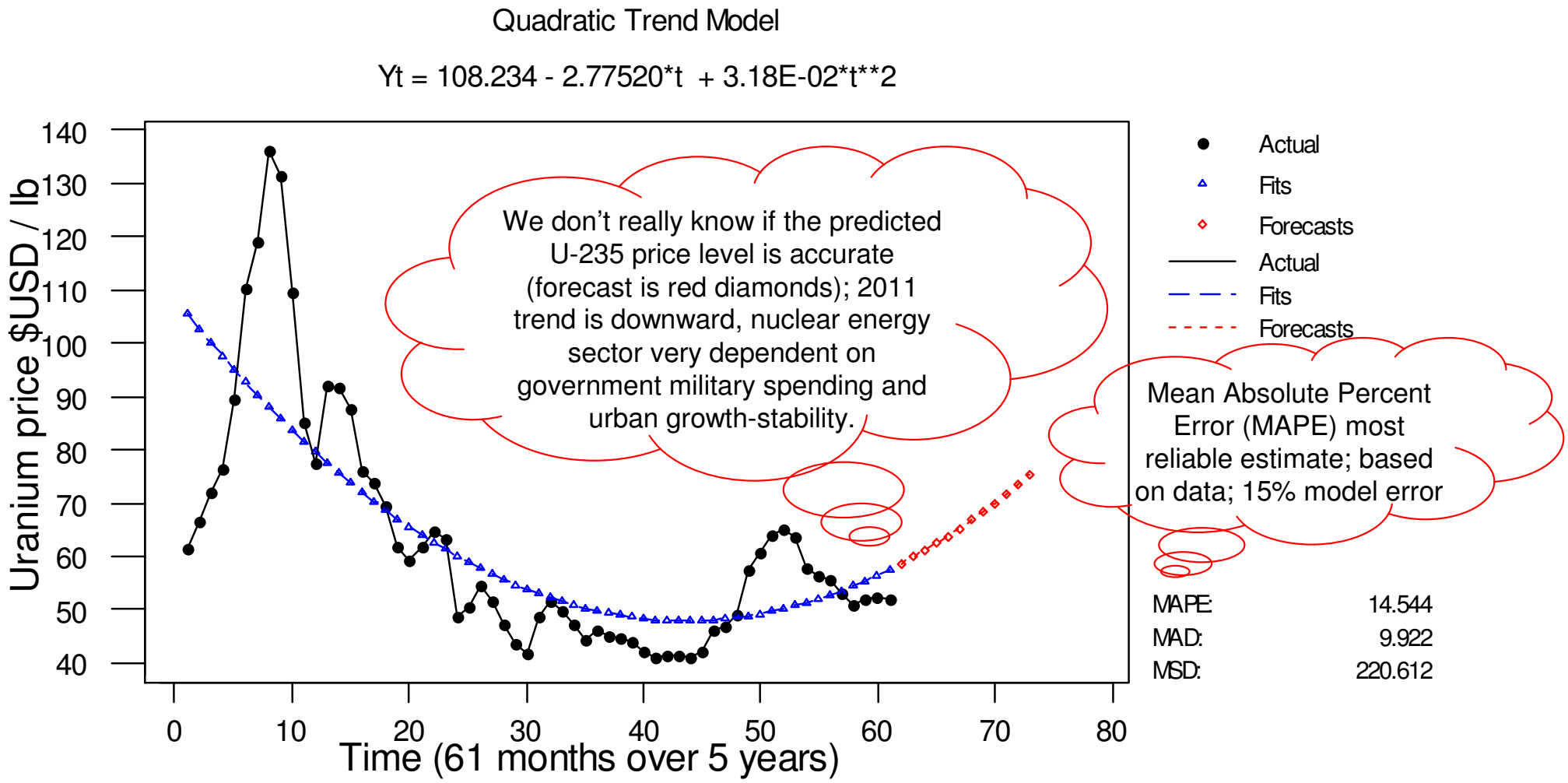
Null hypothesis: M1 <= M2 Alternate hypothesis: M1 => M2 (1-tailed)

OR

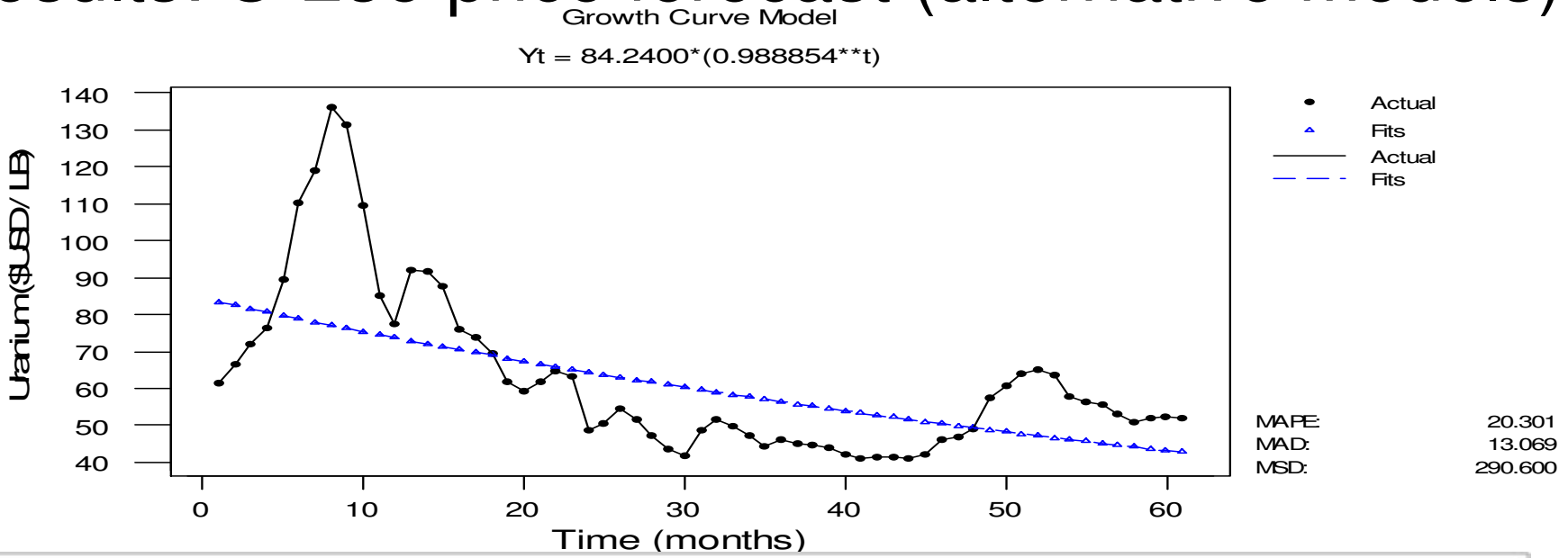
Null hypothesis: M1 = M2 Alternate hypothesis: M1 <> M2 (2-tailed)

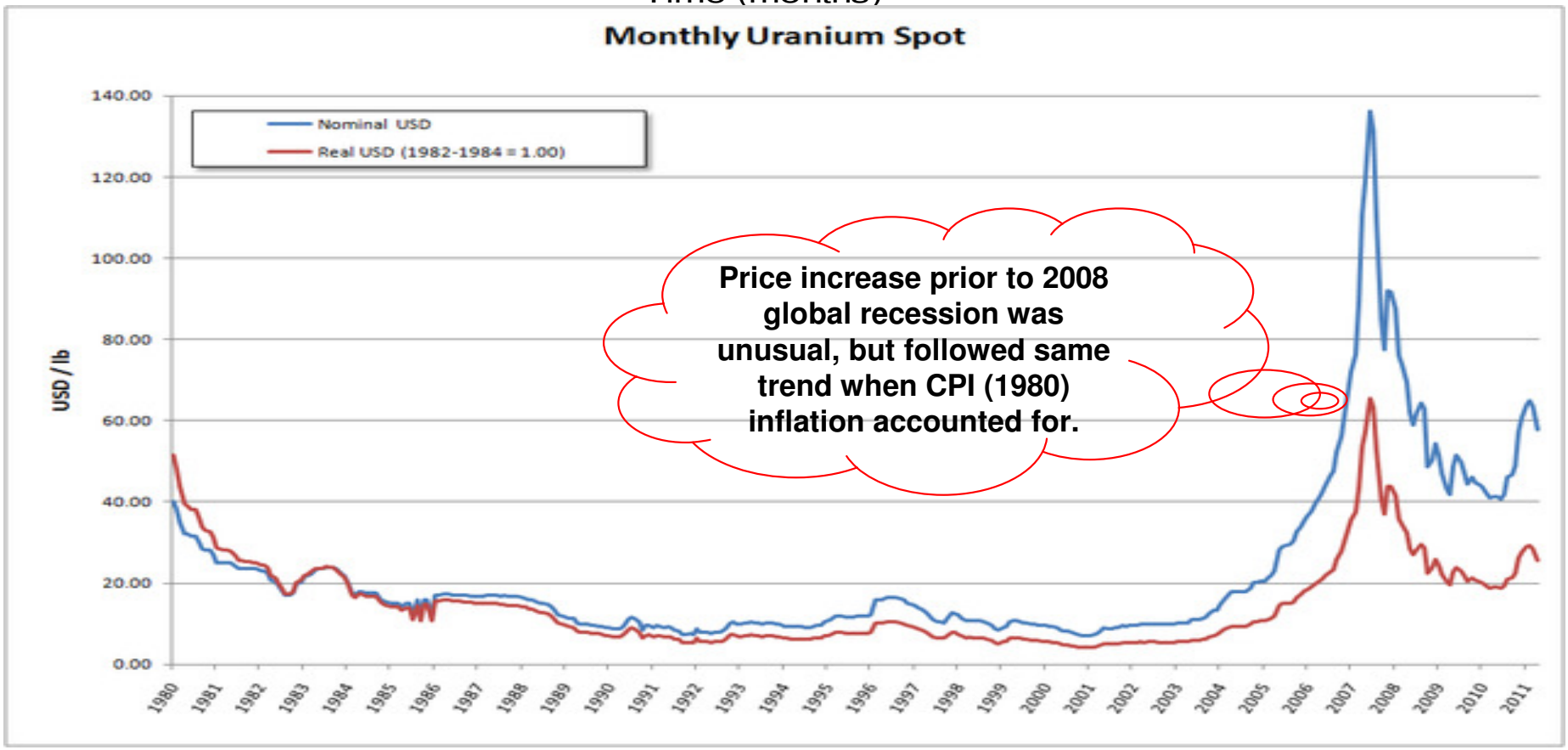
Results: U-235 price forecast (best model)

- All models except quadratic (squared regression) have high MAPE > 20%
- All other models plot a negative linear pattern (indicates prices on decline)
- Quadratic forecast shows an exponential curved slope (lowest in fall 2008)
- Quadratic model predicts prices to rise = industry expert qualitative opinions
- Caveat: market is volatile, no reliable correlation with NYSE or crude oil prices
- Recommendation: use recent 2011 U-235 price $51.75/lb for evaluation model.



Results: U-235 price forecast (alternative models)





Results: U-235 global demand forecast

	NUCLEAR ELECTRICITY GENERATION 2011		REACTORS OPERABLE		REACTORS UNDER CONSTRUCTION		REACTORS PLANNED		REACTORS PROPOSED		URANIUM REQUIRED 2011	U-235
	billion kWh	% e	OR	MWe net	No.	MWe gross	No.	MWe gross	No.	MWe gross	tonnes U	Pounds
USA	807.1	19.6	**104**	101421	1	1218	6	7200	28	38600	19427	38,854,000
France	410.1	74.1	**58**	63130	1	1720	1	1720	1	1100	9221	18,442,000
Japan	280.3	29.2	**51**	44642	2	2756	10	13772	5	6760	8195	16,390,000
Russia	159.4	17.8	**32**	23084	10	8960	14	16000	**30**	28000	3757	7,514,000
Korea South	141.1	32.2	**21**	18716	5	5800	6	8400	0	0	3586	7,172,000
India	20.5	2.9	**20**	4385	5	3900	18	15700	**40**	49000	1053	2,106,000
Canada	85.5	15.1	18	12679	2	1500	3	3300	3	3800	1884	3,768,000
UK	56.9	15.7	18	10745	0	0	4	6680	9	12000	2235	4,470,000
Germany	133	28.4	17	20339	0	0	0	0	0	0	3453	6,906,000
Ukraine	83.95	48.1	15	13168	0	0	2	1900	20	22800	2037	4,074,000
China	71	1.8	14	11271	26	28710	52	59990	**120**	123000	4402	8,804,000
Sweden	55.7	38.1	10	9399	0	0	0	0	0	0	1537	3,074,000
Spain	59.3	20.1	8	7448	0	0	0	0	0	0	1458	2,916,000
Belgium	45	51.7	7	5943	0	0	0	0	0	0	1052	2,104,000
Taiwan	39.9	19.3	6	4927	0	0	0	0	0	0	0	-
Czech Rep.	26.4	33.2	6	3722	0	0	2	2400	1	1200	680	1,360,000
Switzerland	25.3	38	5	3252	0	0	0	0	3	4000	557	1,114,000
Finland	21.9	28.4	4	2721	1	1700	0	0	2	3000	468	936,000
Hungary	14.7	42.1	4	1880	0	0	0	0	2	2200	295	590,000
Slovakia	13.5	51.8	4	1816	2	880	0	0	1	1200	267	534,000
Pakistan	2.6	2.6	3	725	1	340	1	340	2	2000	68	136,000
Bulgaria	14.2	33.1	2	1906	0	0	2	1900	0	0	275	550,000
Brazil	13.9	3.1	2	1901	1	1405	0	0	4	4000	311	622,000
South Africa	12.9	5.2	2	1800	0	0	0	0	6	9600	321	642,000
Mexico	5.6	3.6	2	1600	0	0	0	0	2	2000	247	494,000
Romania	10.7	19.5	2	1310	0	0	2	1310	1	655	175	350,000
Argentina	6.7	5.9	2	935	1	745	2	773	1	740	208	416,000
Slovenia	5.4	37.9	1	696	0	0	0	0	1	1000	145	290,000
Netherlands	3.75	3.4	1	485	0	0	0	0	1	1000	107	214,000
Armenia	2.3	39.4	1	376	0	0	1	1060	0	0	56	112,000
Iran	0	0	0	0	1	1000	2	2000	1	300	150	300,000
Total	1821.5	741.7	**336**	275001	58	59416	142	156645	**293**	324005	48200	96,400,000
WORLD**	**2630**	**13.8**	**440**	**376,442**	**61**	**63,334**	**154**	**171,445**	**343**	**391,355**	**68,971**	137,942,000

Under construction

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Global U-235 demand

Results: U-235 client demand surveys (n=34)

- Clients typically government, project A & C demand varies due to delivery plan
- Logistic costs (storage, shipping, import tariffs) deducted from supply in model
- Use linear programming for mining operations
- Uses mean demand forecast to allocate supply
- Average client demand: 219118 vs. 220265 lbs
- ProjectC higher average expected value +$60K

Project decision making	ProjectA	ProjectC
U2 Price in 2011 $USD/lb	51.75	51.75
Mean demand x 1000	$11,339,338	$11,398,699

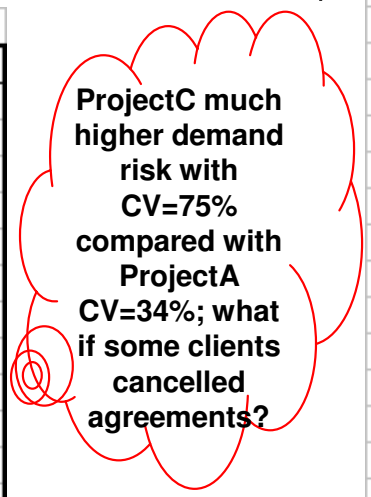
- Hypothesis: mean demand NOT > 230,000 lbs

Project A & C: T-Test mu = 230.0 vs. mu > 230.0

A: T= -0.86, P= 0.80; C: T= -0.35, P= 0.63, α=5%

Wilcoxon Signed Rank Test (about same result)

Descriptive statistics from client demand surveys		
Project cashflow NPV n=34	*ProjectA*	*ProjectC*
Mean	219.118	220.265
Median	226.500	139.000
Standard Deviation	73.403	164.477
Kurtosis	-0.888	-1.187
Skewness	-0.206	0.551
Range	265.000	482.000
Minimum	74.000	30.000
Maximum	339.000	512.000
CV	0.335	0.747
sum	7450	7489
N (size)	34	34
Probability U235 mean>230/lb	0.441	0.476



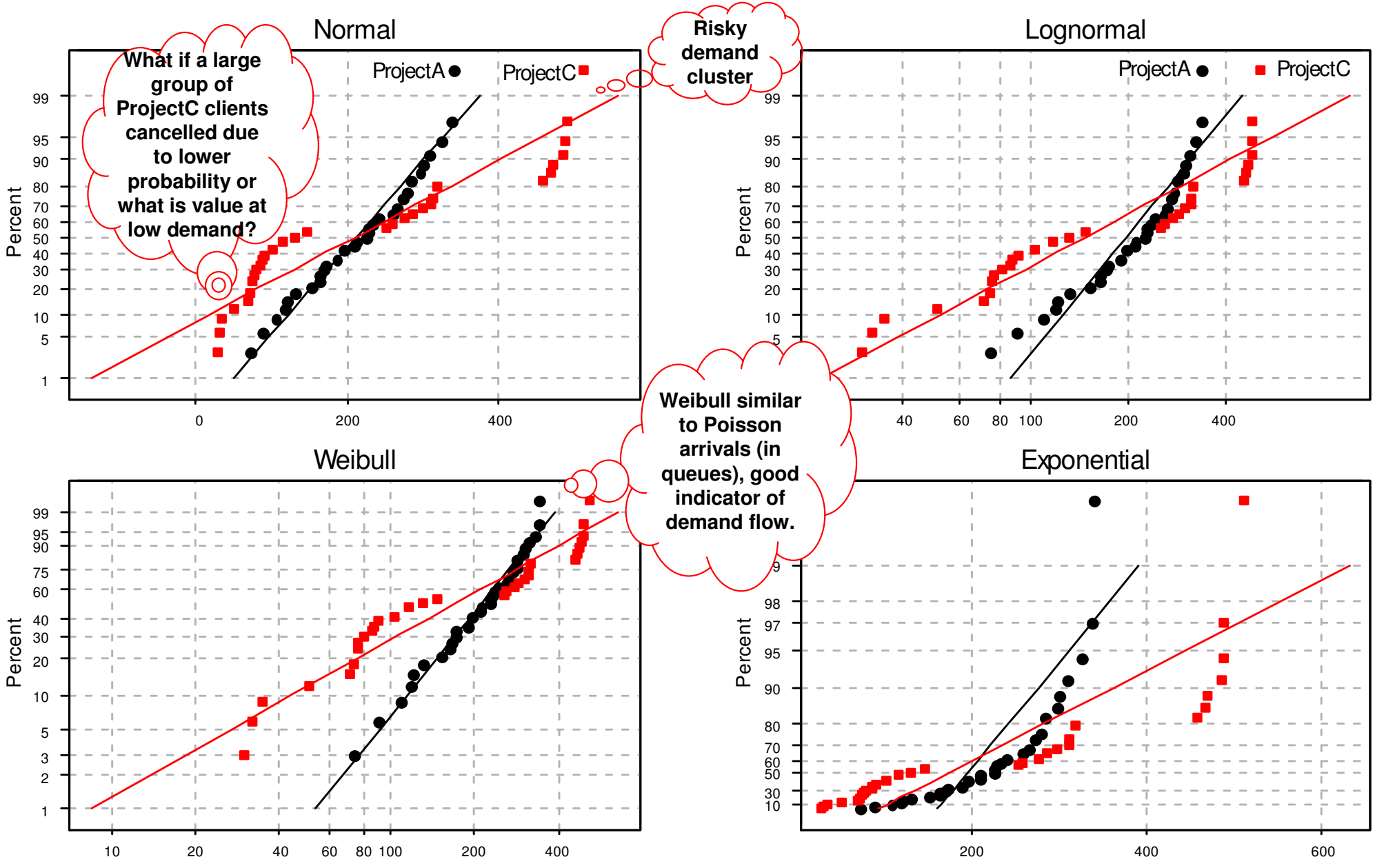
Uranium Demand (000's)	ProjectA	ProjectC
Argentina	172	86
Armenia	131	74
Belgium	241	277
Brazil	211	117
Bulgaria	196	103
Canada	273	318
China	309	488
Czech Rep.	234	259
Finland	227	147
France	337	512
Germany	284	470
Hungary	210	117
India	259	299
Italy	90	32
Japan	325	489
Kazakhstan	74	30
Korea South	298	318
Mexico	188	88
Netherlands	163	76
Pakistan	152	76
Romania	170	81
Russia	301	485
Slovakia	196	91
Slovenia	164	77
South Africa	226	131
Spain	265	312
Sweden	273	313
Switzerland	229	253
Taiwan	121	71
Thailand	119	51
UAE	109	35
UK	284	286
Ukraine	280	459
USA	339	468

Discussion: U-235 demand distribution analysis

Beyond normal distribution, ProjectC demand clustered & volatile = risky

Each block represents a project A or C client, by demand and probability

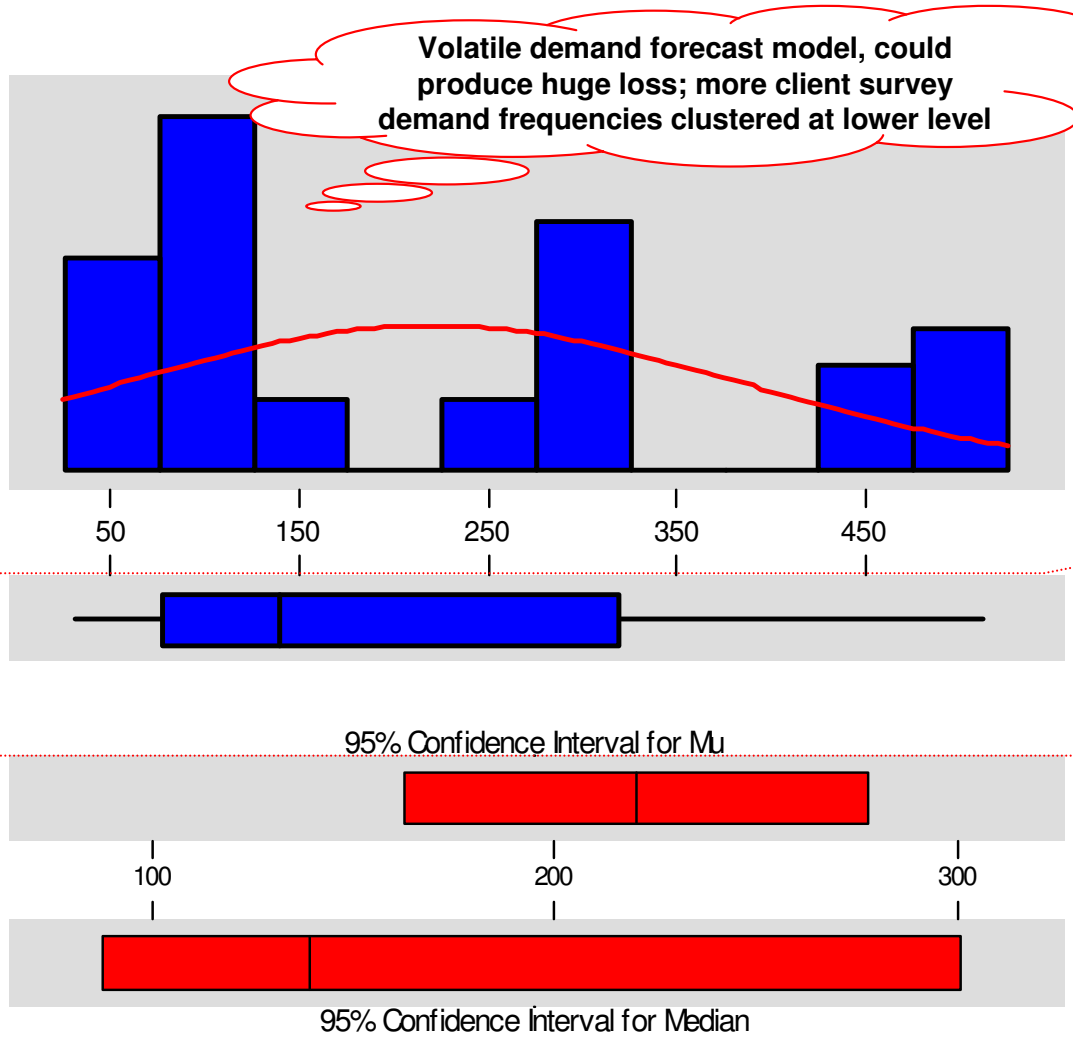
Uranium cumulative demand probability for ProjectA-ProjectC



Discussion: ProjectC nonparametric analysis

- ProjectC client demand distribution does NOT approximate normal distribution
- Median tests, box-transformations, are nonparametric techniques, if above true
- Two problems: high standard deviation, low median as compared with mean
- Most client demand frequencies are concentrated at left, when right skewed

Descriptive statistics (uranium forecast 000's)



U235 scenario project C

Not a normal distribution

Anderson-Darling Normality Test

A-Squared:	1.820
P-Value:	0.000

Median < Mean if Skew > 0, Large SD

Mean	220.265
StDev	164.477
Variance	27052.7
Skewness	0.503488
Kurtosis	-1.29543
N	34

Minimum	30.000
1st Quartile	76.750
Median	139.000
3rd Quartile	318.000
Maximum	512.000

95% Confidence Interval for Mu

162.875	277.654

95% Confidence Interval for Sigma

132.663	216.498

95% Confidence Interval for Median

87.752	300.613

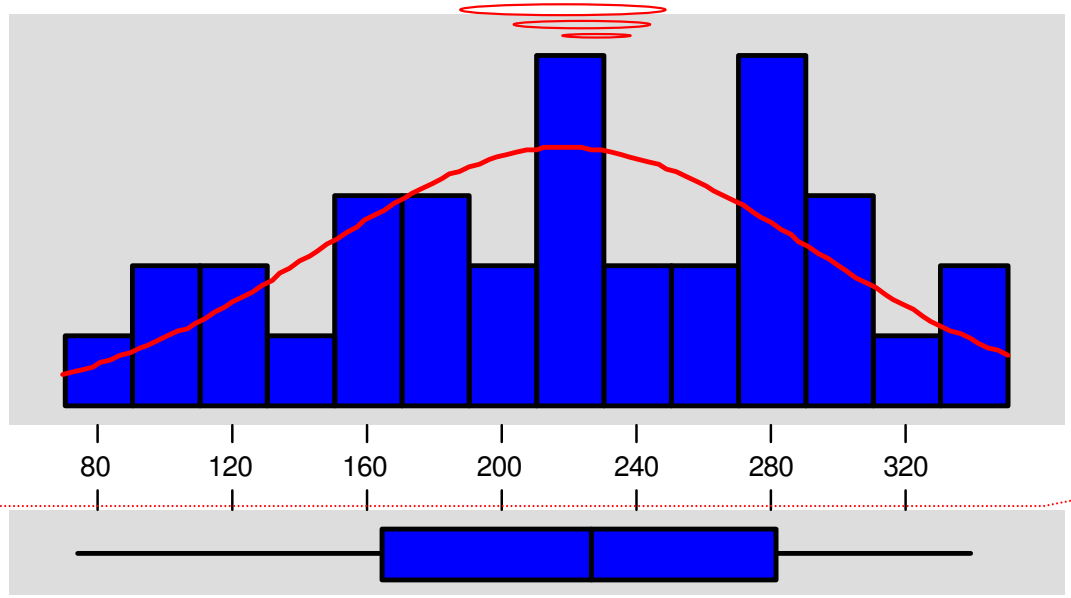
Discussion: ProjectA nonparametric analysis

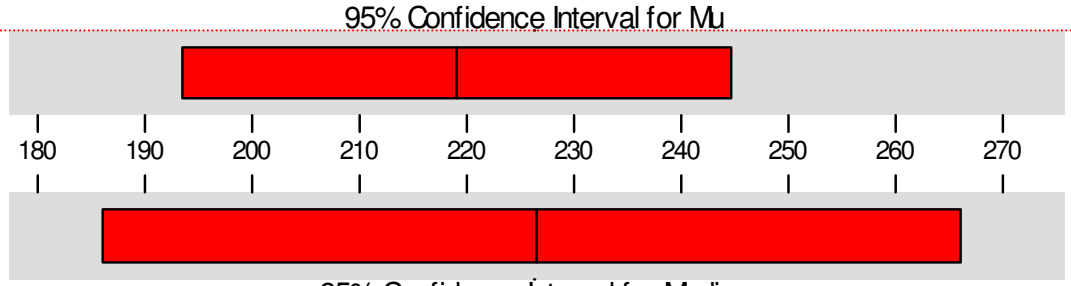
- Most client demand frequencies (probabilities) concentrated in middle & right
- ProjectA median predicts higher expected value (mean substitute, less outliers)
- Prefer expected client demand level forecast above median, not dispersed below mean.

Project decision making	ProjectA	ProjectC
U2 Price in 2011 $USD/lb	51.75	51.75
Mean demand x 1000	$11,339,338	$11,398,699
Median demand x 1000	$11,721,375	$7,193,250
Project A-C median profit	$4,528,125	

Descriptive statistics (uranium forecast 000's)

Normal demand model, reliable mean & median forecast





U235 scenario project A

Approximates normal distribution

Anderson-Darling Normality Test

A-Squared:	0.273
P-Value:	0.647
Mean	219.118
StDev	73.403
Variance	5387.99
Skewness	-1.9E-01
Kurtosis	-1.05357
N	34

Median > Mean if Skew < 0, smaller SD

Minimum	74.000
1st Quartile	163.750
Median	226.500
3rd Quartile	281.000
Maximum	339.000

95% Confidence Interval for Mu

193.506 244.729

95% Confidence Interval for Sigma

59.205 96.619

95% Confidence Interval for Median

186.014 265.993

Conclusions & Implications

1. Recommendation 1: uranium project A
   - Although not much difference in mean profit forecast (ProjectC +$60K)
   - ProjectA $4.5 million higher profitability forecast based on median probability (ProjectC demand risky due to high standard deviation, low median)
   - Mean client demand not > 230,000 lbs 3-24 months (95% probability)
   - Uranium prices may rise slightly (quadratic growth model 15% error)

Project decision making	ProjectA	ProjectC
U2 Price in 2011 $USD/lb	51.75	51.75
Mean demand x 1000	$11,339,338	$11,398,699
Median demand x 1000	$11,721,375	$7,193,250
Project A-C median profit	$4,528,125	

2. Recommendation 2: corroborate findings through multiple methods
   - Triangulate both data sources and techniques (parametric & nonparametric)
   - Read qualitative information from industry experts or peer-reviewed literature
   - Quantitative techniques need to consider CPI and macro-environment factors
   - Analyze distributions beyond descriptive statistics, t-tests, historical forecasts
   - Financial best-practice: if skew < 0, median likely to be higher than mean
   - Risk = coefficient of variation = standard deviation / mean
3. Implications for evaluation research practice in mining industry
   - Evaluate investment projects from different data and technique views
   - Get client opinions (survey data), don't forecast just from past supply
   - Use various horizons in time series forecasts (trends may reverse slope)
   - Sensitivity analysis not sufficient (changing value of one variable per run)
   - Scenario analysis better (changing multiple values such as payoff tables)
   - Check correlation of model factors with one another & macro-environment
   - Statistics: use larger samples, replicate, compare with known models

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