Technomics
Better Decisions Faster

Risky Business: Navigating the World of Software Productivity

Presented to ICEAA Professional Development & Training Workshop

May 2024

Dave Brown, Technomics
Kevin Cincotta, The MITRE Corporation

Welcome

Dave Brown

Technomics

Mr. Dave Brown is an ICEAA certified (CCEA/SCEC) cost analyst with 31 years of experience in life cycle cost analysis, applied cost estimating, cost research, program management support, modeling and simulation, data analysis, and database development. Majority of experience in the estimation and analysis of AIS acquisitions and AIS O&M.

Email: dbrown@technomics.net
Phone: 571-366-1439

Kevin Cincotta

The MITRE Corporation

A Principal Cost Analyst with The MITRE Corporation, Kevin provides technical leadership for projects within MITRE's Center for National Security, primarily supporting DoD and DHS. He leads MITRE's Cost Analysis Community of Practice, is the current ICEAA Certification Principal, and a CCEA/SCEC certification holder. He has over 25 years of cost-related consulting experience and served as the lead reviewer of the CEBoK-S. Kevin won the organization's prestigious award for Service to the Association in 2023.

Email: kcincotta@mitre.org
Phone: 703-983-0184

Our paper is available on the Whova app

Introduction & Problem Statement

- *Productivity* is an essential component to any estimate of software development
- Because productivity is never known in advance, it must be estimated
- Proper treatment of risk and uncertainty requires the analyst to understand and model the uncertainty distribution surrounding productivity

- This presentation will:
  - Offer an alternative way to incorporate productivity in the estimating process
  - Offer an alternative way to model productivity risk and uncertainty
  - Show how these results can improve any software estimate

Productivity as a Concept

- One of two primary cost drivers (along with size) to any software estimate
- Measured as output divided by input
  - For example, Size divided by effort. Function Points divided by person-hours.
  - Can be viewed as either an estimating input or output

Measured By:

Output:

- Function Points
- SLOC
- Story Points
- # of Requirements
- Simple Function Points
- Use Case Points

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Input:

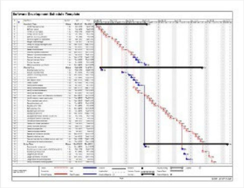
- Person-hours
- Person-months
- Person-years

Influenced By:

- Complexity

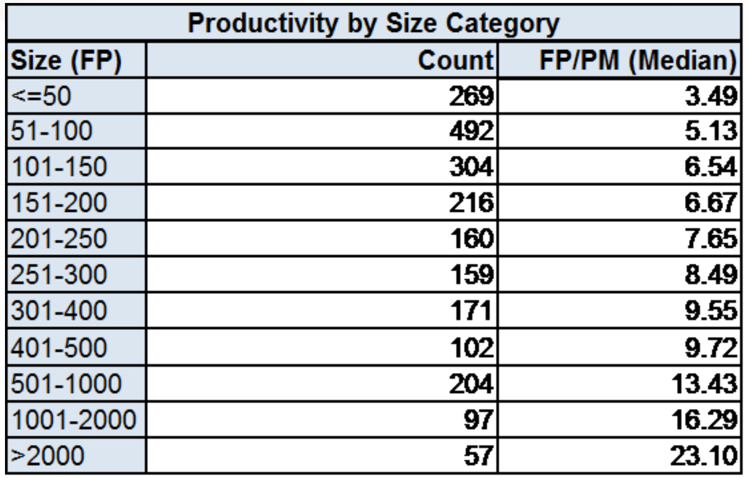
- Capability

- Schedule



Productivity as an Input

- An assumed factor
  - This published table shows typical productivity (measured as FP/PM), based on the size of the project. The count column indicates the number of projects in the underlying dataset.
- Analogy
  - A typical approach would be to find an analogous project, with measured actual productivity. Apply that value to the estimated project by estimating size divided by productivity.
- Database Average
  - Use a database of many analogous projects, and calculate average productivity. Apply that value to the estimate



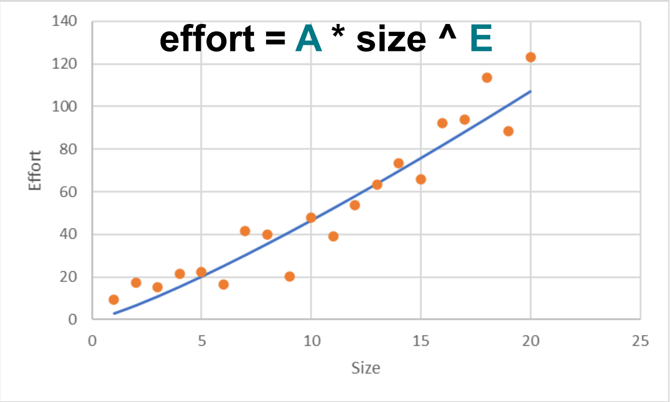
Productivity by Size Category

Size (FP)	Count	FP/PM (Median)
<=50	269	3.49
51-100	492	5.13
101-150	304	6.54
151-200	216	6.67
201-250	160	7.65
251-300	159	8.49
301-400	171	9.55
401-500	102	9.72
501-1000	204	13.43
1001-2000	97	16.29
>2000	57	23.10

Productivity as an Output

$$\text{Effort} = 2.94 * \text{KESLOC}^{E} * \text{EAF}$$

- COCOMO II model. Effort multiplier (EM) factors measure software complexity and team capability. Together, they capture productivity.
- Custom Effort Estimating Relationship. If a database of analogous projects is available, then a relationship between size and effort can be statistically derived.
- Software estimating tool. Commercial tools allow estimation of software effort based on multiple parameters that may not include a direct productivity parameter



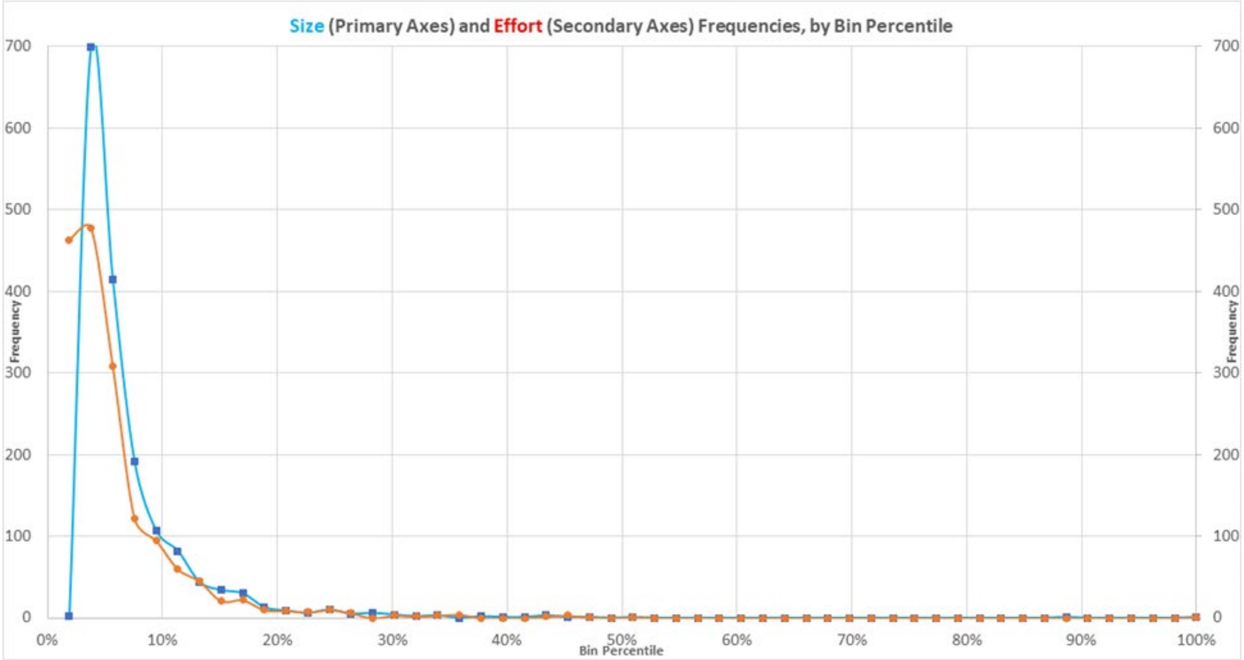
- In each of these cases, productivity can be calculated post-hoc using the standard metric of size divided by effort
- Productivity still exists! It still carries uncertainty.

Our Dataset: ISBSG

- International Software Benchmarking Standards Group (ISBSG) is a database containing software project data across the industry, https://www.isbsg.org/
  - Data submitted by IT and metrics organizations
  - 20+ Industry Sectors
  - 10,600 observations (projects)
  - Projects from 1989 to 2022
  - 252 fields of variables. Quantitative: 105, Qualitative: 147
  - U.S. and International data
- Effort, reported as person-hours reported for all projects
  - Project activity scope is specified for each project
  - We filtered for: “design; build; test; implement”, which is the most frequently reported scope
- Size, reported based on a variety of different metrics
  - Most prevalent size metric is adjusted function points, using an IFPUG 4+ standard
- Data quality rating, A through D
  - We used only A or B

Size and Effort in Isolation

- Both size and effort, plotted as a PDF-style distribution:



- Statistics:

Statistic	Size
Mean	128.5
Median	87.0
StDev	126.1
Skewness	0.988
CV	98%
Min	7
Max	2,048

Statistic	Effort
Mean	1,744
Median	1,165
StDev	2,103
Skewness	0.826
CV	121%
Min	0
Max	35,063

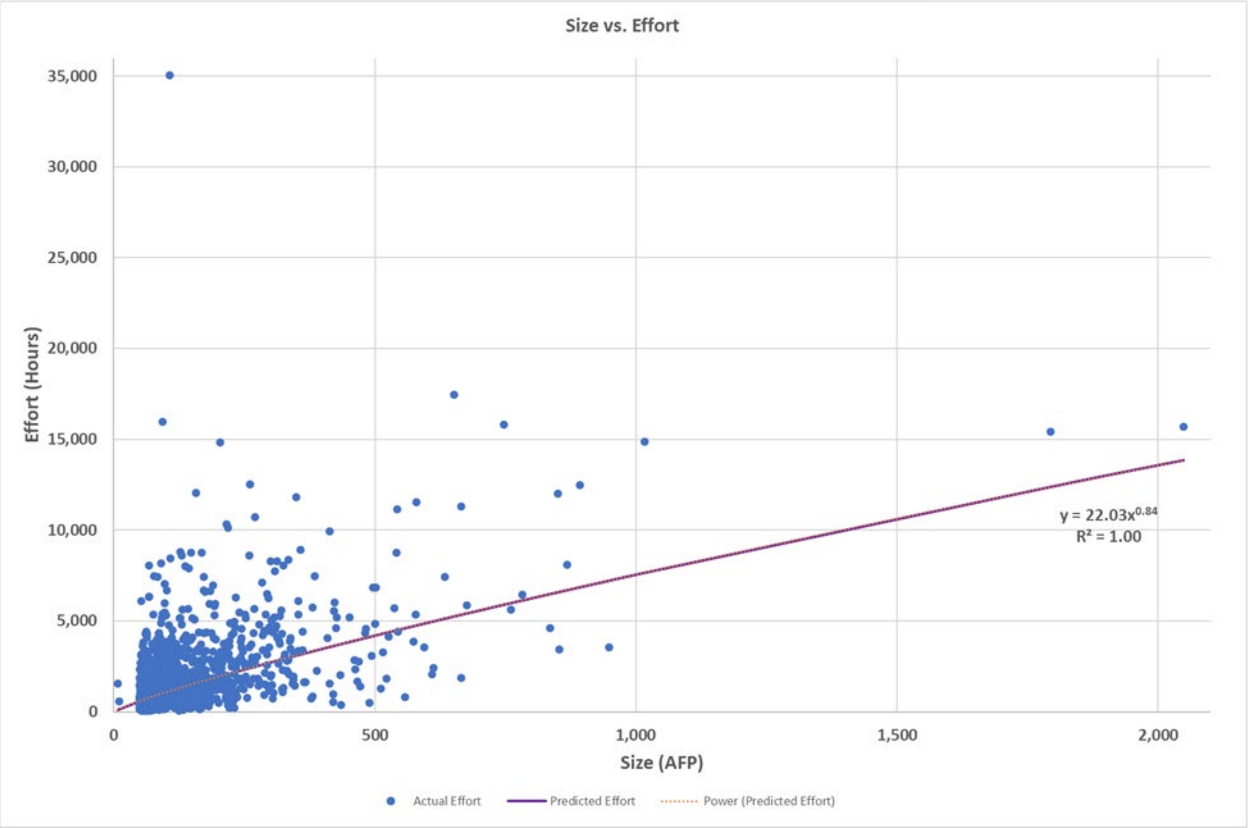
- Both are significantly right-skewed

Initial Analysis of Productivity

- Size versus Effort on a scatterplot:
  - Exponent indicates economy of scale
- Statistics:

Statistic	Productivity (AFP/MH)
Mean	0.1369
Median	0.0876
StDev	0.1601
Skewness	0.923
CV	117%
Min	0.0031
Max	2.0667

- Positive correlation is apparent
- CV (117%) indicates high variability
- Curve is slightly *concave-down*

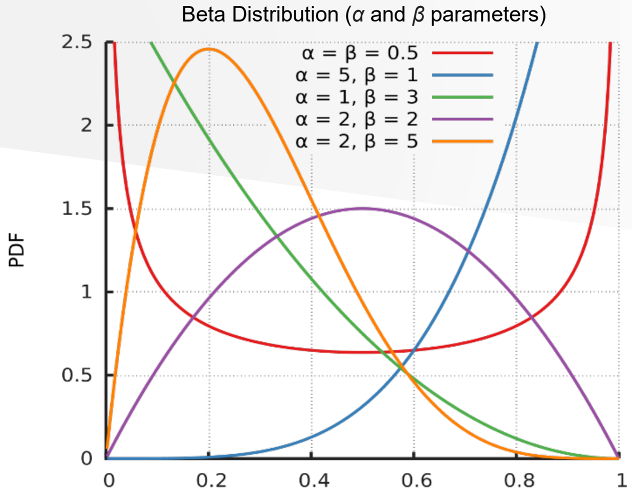


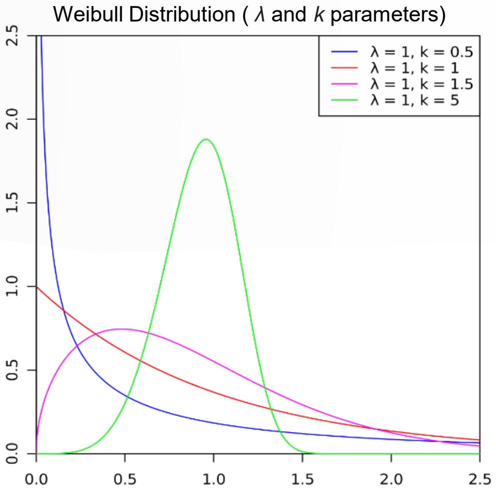
Productivity should not be treated as known or constant. Risk and uncertainty analysis is essential!

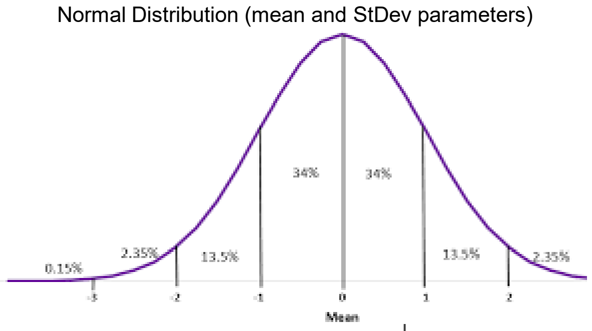
Candidate Distributions

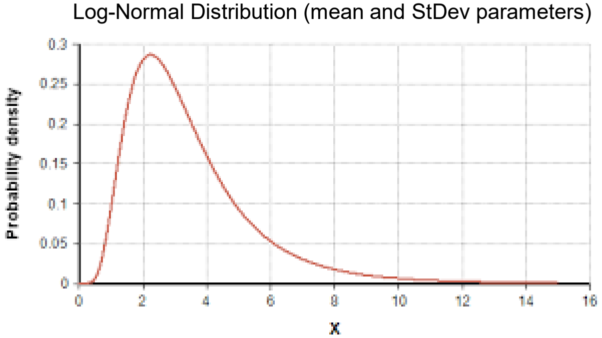
- Beta
- Weibull (“the Gumby distribution” because it fits anything!)
- Normal
- Lognormal
- Triangular (three-point estimate)
- Normal Method of Moments

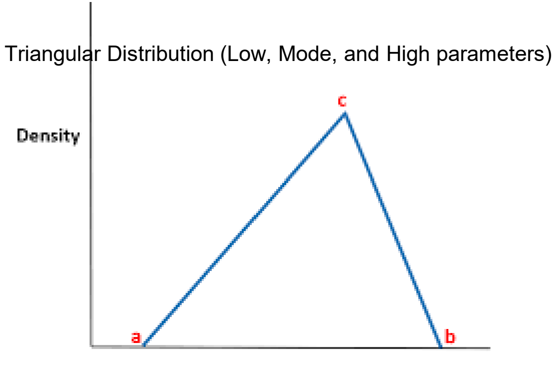
- Other considerations
  - Bin width: Scott’s
  - Method of specifying distributional parameters: fitting via a penalty function


Beta Distribution (α and β parameters)


Weibull Distribution (λ and k parameters)


Normal Distribution (mean and StDev parameters)


Log-Normal Distribution (mean and StDev parameters)

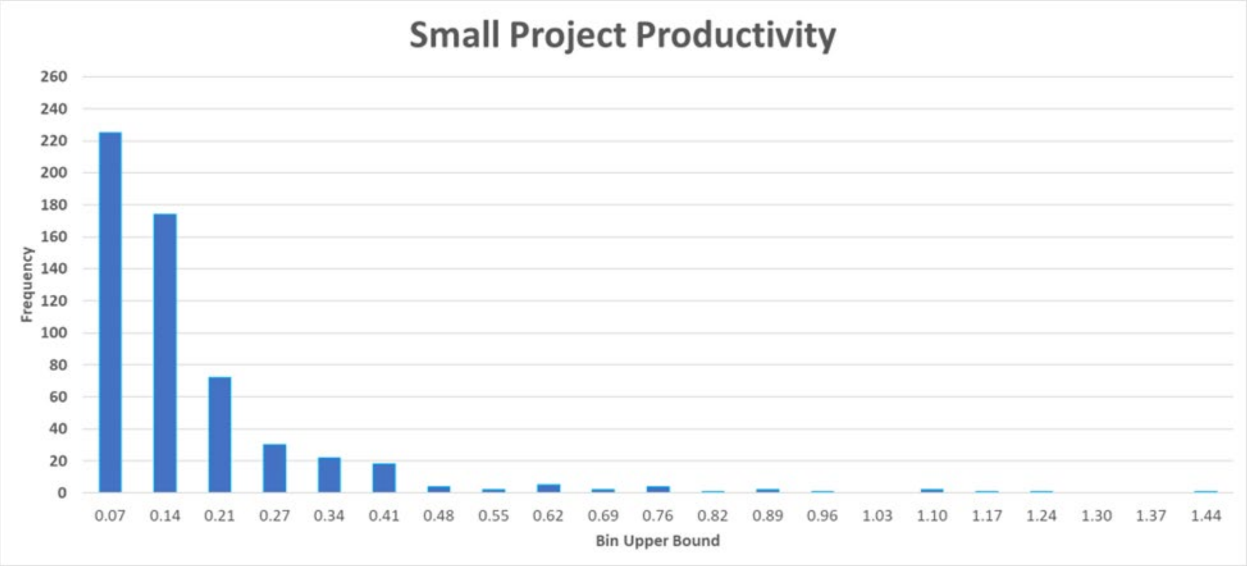

Triangular Distribution (Low, Mode, and High parameters)

How We Tested the Distributions

- Scott's bin width
- Minimize Sum of Squared Errors (SSE) between observed and expected frequencies
- Calculate Chi-Square Statistic (CSS) and associated p-value for eligible bins
- Used much smaller bin sizes ("microbins") for graphing

Small Projects

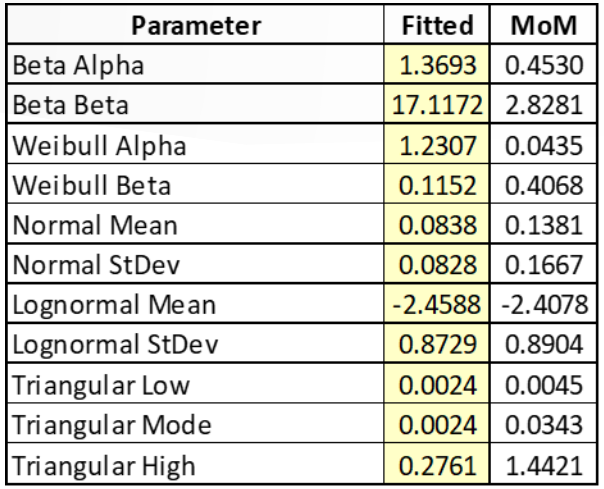
- Small projects have size <= 70 AFP. 567 data points, roughly 1/3 of our dataset
- Highly right-skewed distribution
  - Observable from the histogram
  - Skewness statistic is >0 and mean > median
  - Suggests normal may not be the best fitting distribution
- High CV (121%) suggests high variability and uncertainty



Statistic	Size	Effort	Productivity
Mean	59.4	936	0.1381
Median	59.0	716	0.0826
StDev	6.9	888	0.1667
Skewness	0.181	0.742	0.999
CV	12%	95%	121%
Min	7	48.54	0.0045
Max	70	8,044	1.4421

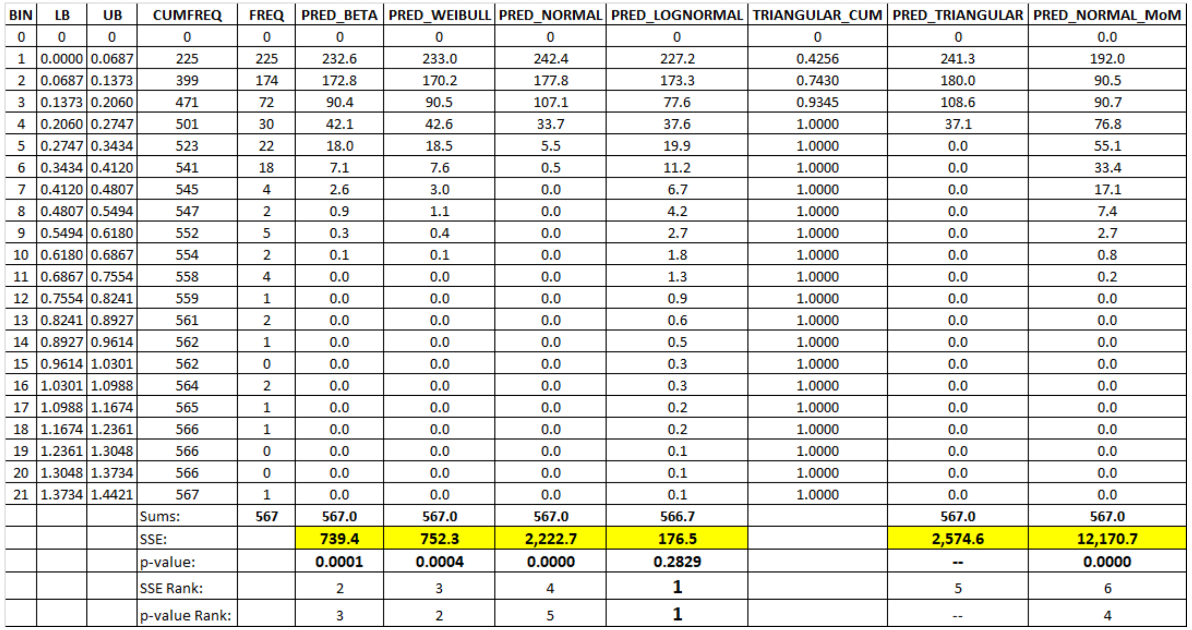
Small Project Productivity Parameters

- Fitted parameters for each distribution are shown in the first table
- Method of Moments (MoM) is calculated by assuming the parameters of the data (e.g. mean and StDev) are the same as the parameters of the distribution



Parameter	Fitted	MoM
Beta Alpha	1.3693	0.4530
Beta Beta	17.1172	2.8281
Weibull Alpha	1.2307	0.0435
Weibull Beta	0.1152	0.4068
Normal Mean	0.0838	0.1381
Normal StDev	0.0828	0.1667
Lognormal Mean	-2.4588	-2.4078
Lognormal StDev	0.8729	0.8904
Triangular Low	0.0024	0.0045
Triangular Mode	0.0024	0.0343
Triangular High	0.2761	1.4421

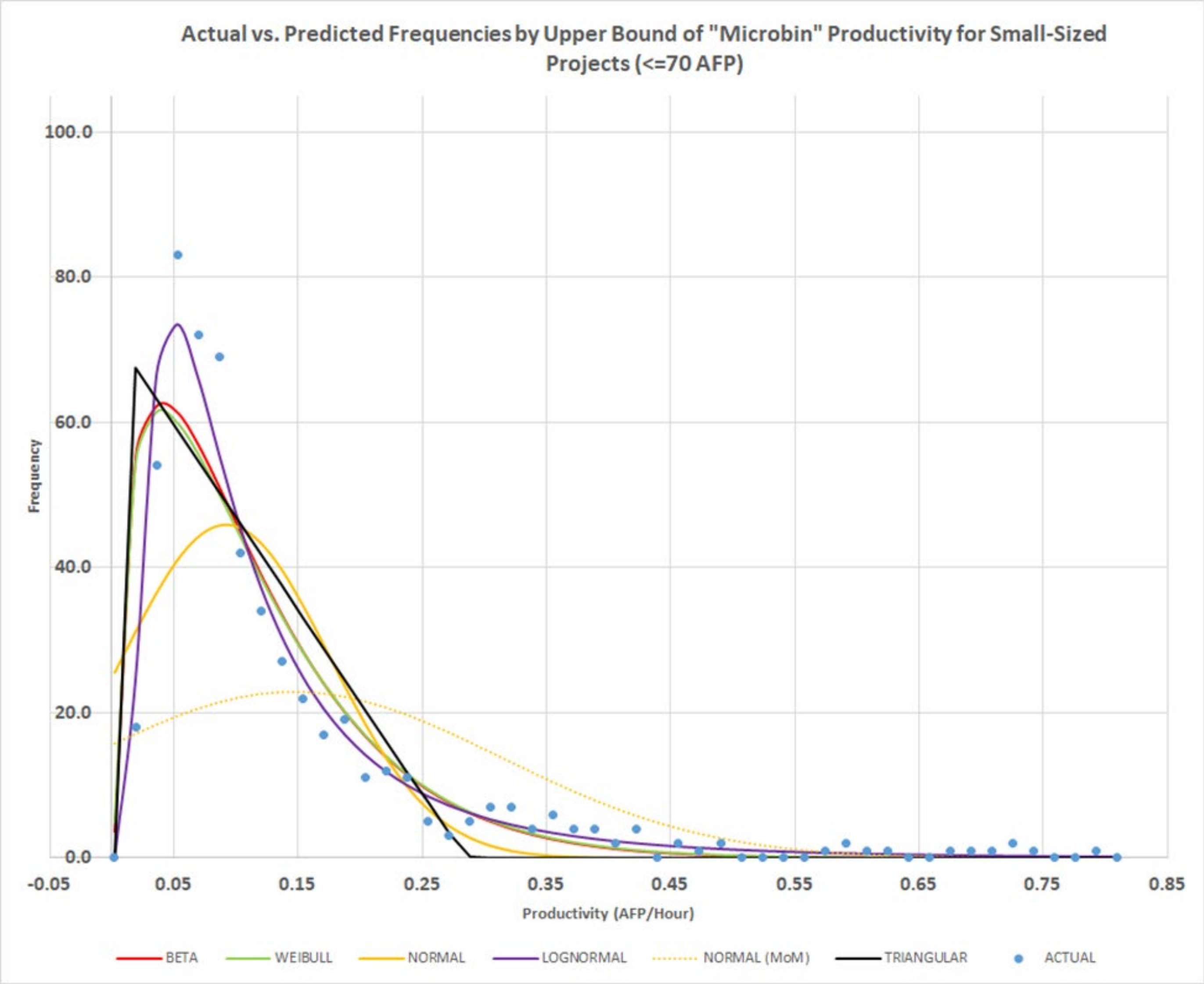
- Second chart shows SSE and p-values for each distribution
  - Lowest SSE is the best fitting
  - Highest p-value is the most likely that the data perfectly fit the distribution
- Lognormal is best SSE and p-value
  - Significantly better than the 2nd and 3rd best, which are Beta and Weibull



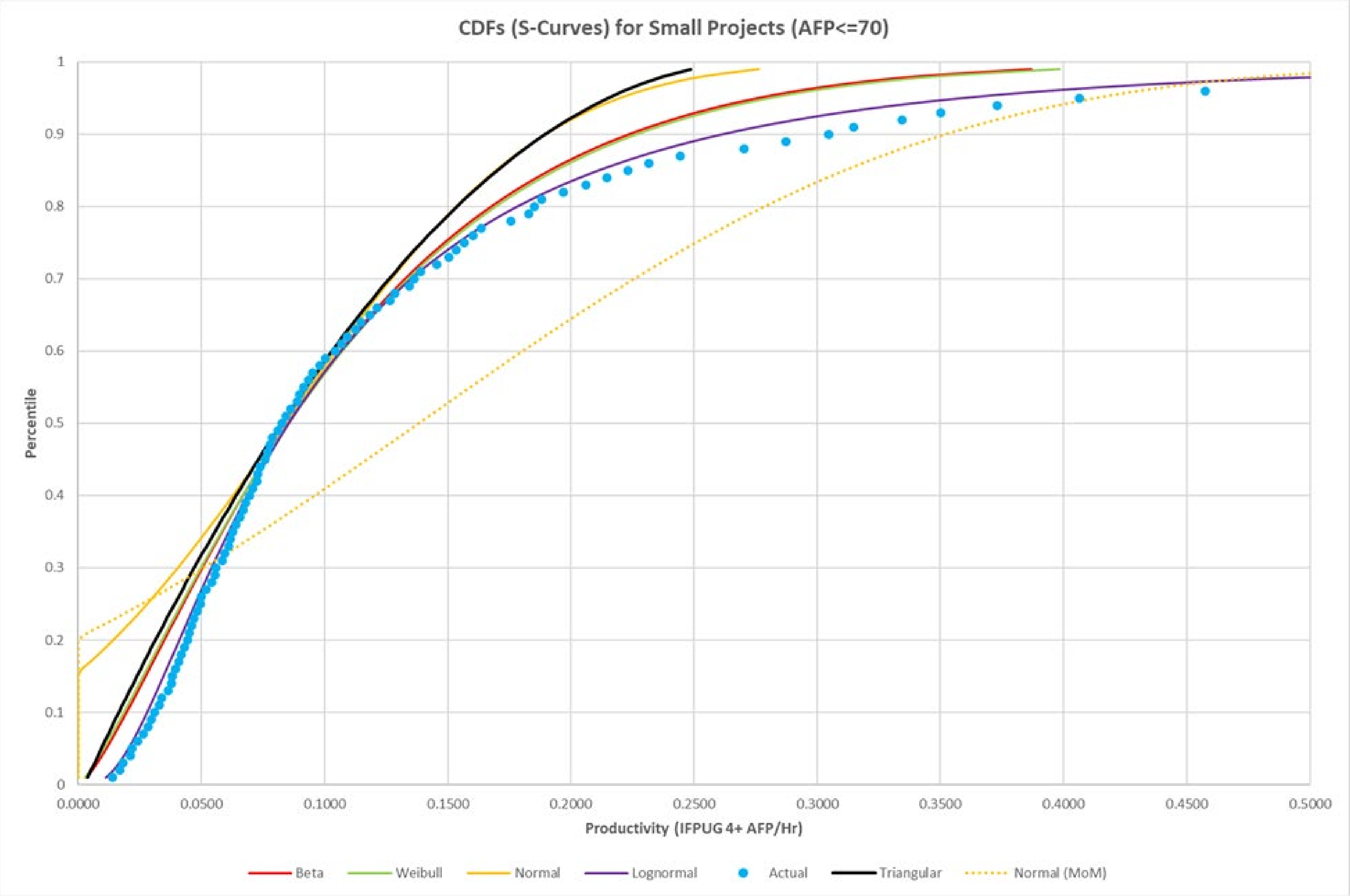
BIN	LB	UB	CUMFREQ	FREQ	PRED_BETA	PRED_WEIBULL	PRED_NORMAL	PRED_LOGNORMAL	TRIANGULAR_CUM	PRED_TRIANGULAR	PRED_NORMAL_MoM
0	0	0	0	0	0	0	0	0	0	0	0.0
1	0.0000	0.0687	225	225	232.6	233.0	242.4	227.2	0.4256	241.3	192.0
2	0.0687	0.1373	399	174	172.8	170.2	177.8	173.3	0.7430	180.0	90.5
3	0.1373	0.2060	471	72	90.4	90.5	107.1	77.6	0.9345	108.6	90.7
4	0.2060	0.2747	501	30	42.1	42.6	33.7	37.6	1.0000	37.1	76.8
5	0.2747	0.3434	523	22	18.0	18.5	5.5	19.9	1.0000	0.0	55.1
6	0.3434	0.4120	541	18	7.1	7.6	0.5	11.2	1.0000	0.0	33.4
7	0.4120	0.4807	545	4	2.6	3.0	0.0	6.7	1.0000	0.0	17.1
8	0.4807	0.5494	547	2	0.9	1.1	0.0	4.2	1.0000	0.0	7.4
9	0.5494	0.6180	552	5	0.3	0.4	0.0	2.7	1.0000	0.0	2.7
10	0.6180	0.6867	554	2	0.1	0.1	0.0	1.8	1.0000	0.0	0.8
11	0.6867	0.7554	558	4	0.0	0.0	0.0	1.3	1.0000	0.0	0.2
12	0.7554	0.8241	559	1	0.0	0.0	0.0	0.9	1.0000	0.0	0.0
13	0.8241	0.8927	561	2	0.0	0.0	0.0	0.6	1.0000	0.0	0.0
14	0.8927	0.9614	562	1	0.0	0.0	0.0	0.5	1.0000	0.0	0.0
15	0.9614	1.0301	562	0	0.0	0.0	0.0	0.3	1.0000	0.0	0.0
16	1.0301	1.0988	564	2	0.0	0.0	0.0	0.3	1.0000	0.0	0.0
17	1.0988	1.1674	565	1	0.0	0.0	0.0	0.2	1.0000	0.0	0.0
18	1.1674	1.2361	566	1	0.0	0.0	0.0	0.2	1.0000	0.0	0.0
19	1.2361	1.3048	566	0	0.0	0.0	0.0	0.1	1.0000	0.0	0.0
20	1.3048	1.3734	566	0	0.0	0.0	0.0	0.1	1.0000	0.0	0.0
21	1.3734	1.4421	567	1	0.0	0.0	0.0	0.1	1.0000	0.0	0.0
			Sums:	**567**	**567.0**	**567.0**	**567.0**	**566.7**		**567.0**	**567.0**
			SSE:		**739.4**	**752.3**	**2,222.7**	**176.5**		**2,574.6**	**12,170.7**
			p-value:		**0.0001**	**0.0004**	**0.0000**	**0.2829**		**--**	**0.0000**
			SSE Rank:		2	3	4	**1**		5	6
			p-value Rank:		3	2	5	**1**		--	4

Small Project Productivity Frequency by “Microbin”

- All distributions tested, and fitted by minimizing sum of squared errors (SSE), using Excel solver
- CDF and PDF graphics compare actuals (blue dots) against each curve
- Purple curve, representing the Lognormal, appears to be the best fit

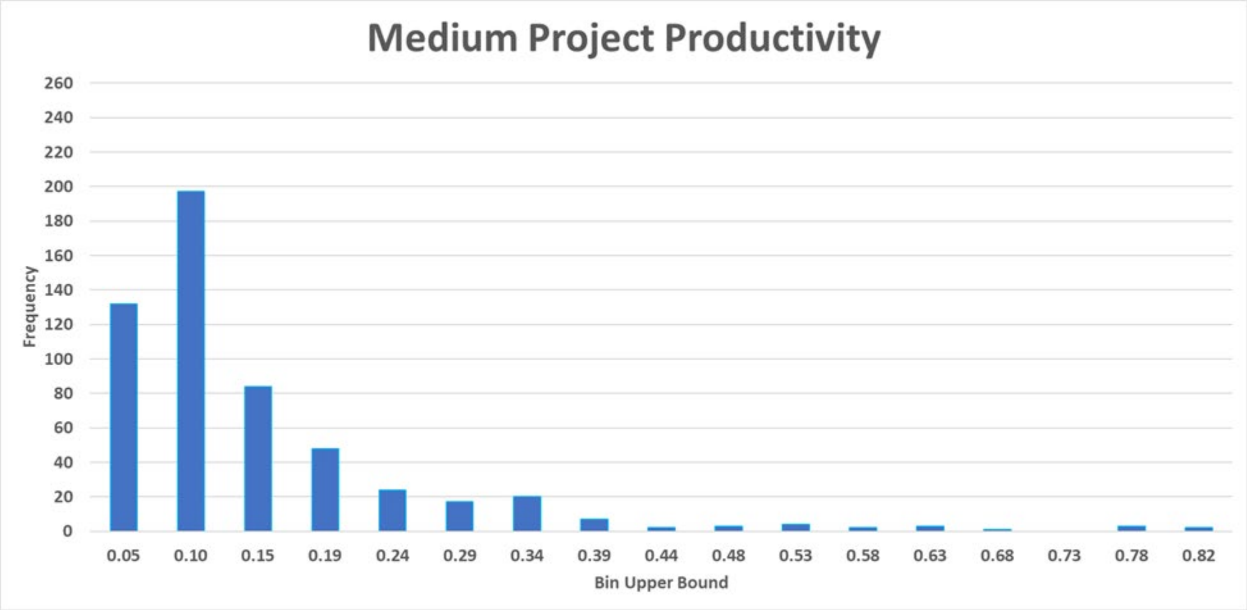


Small Project Productivity Fitted S-Curves



Medium Projects

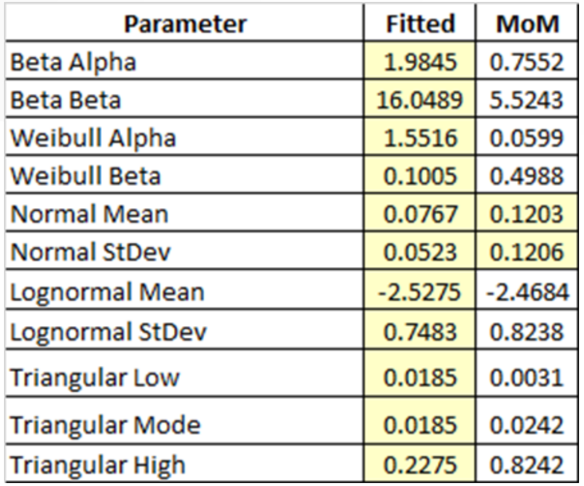
- Medium projects have size > 70 AFP and <= 115 AFP. 549 data points, roughly 1/3 of our dataset
- Highly right-skewed distribution
  - Observable from the histogram
  - Skewness statistic is >0 and mean > median
  - Suggests normal may not be the best fitting distribution
- High CV (100%) suggests high variability and uncertainty



Statistic	Size	Effort	Productivity
Mean	89.7	1,500	0.1203
Median	88.0	1,096	0.0805
StDev	13.0	1,970	0.1206
Skewness	0.382	0.615	0.989
CV	14%	131%	100%
Min	71	91	0.0031
Max	115	35,063	0.8242

Medium Project Productivity Parameters

- Fitted parameters for each distribution are shown in the first table
- Method of Moments (MoM) is calculated by assuming the parameters of the data (e.g. mean and StDev) are the same as the parameters of the distribution



Parameter	Fitted	MoM
Beta Alpha	1.9845	0.7552
Beta Beta	16.0489	5.5243
Weibull Alpha	1.5516	0.0599
Weibull Beta	0.1005	0.4988
Normal Mean	0.0767	0.1203
Normal StDev	0.0523	0.1206
Lognormal Mean	-2.5275	-2.4684
Lognormal StDev	0.7483	0.8238
Triangular Low	0.0185	0.0031
Triangular Mode	0.0185	0.0242
Triangular High	0.2275	0.8242

- Second chart shows SSE and p-values for each distribution
  - Lowest SSE is the best fitting
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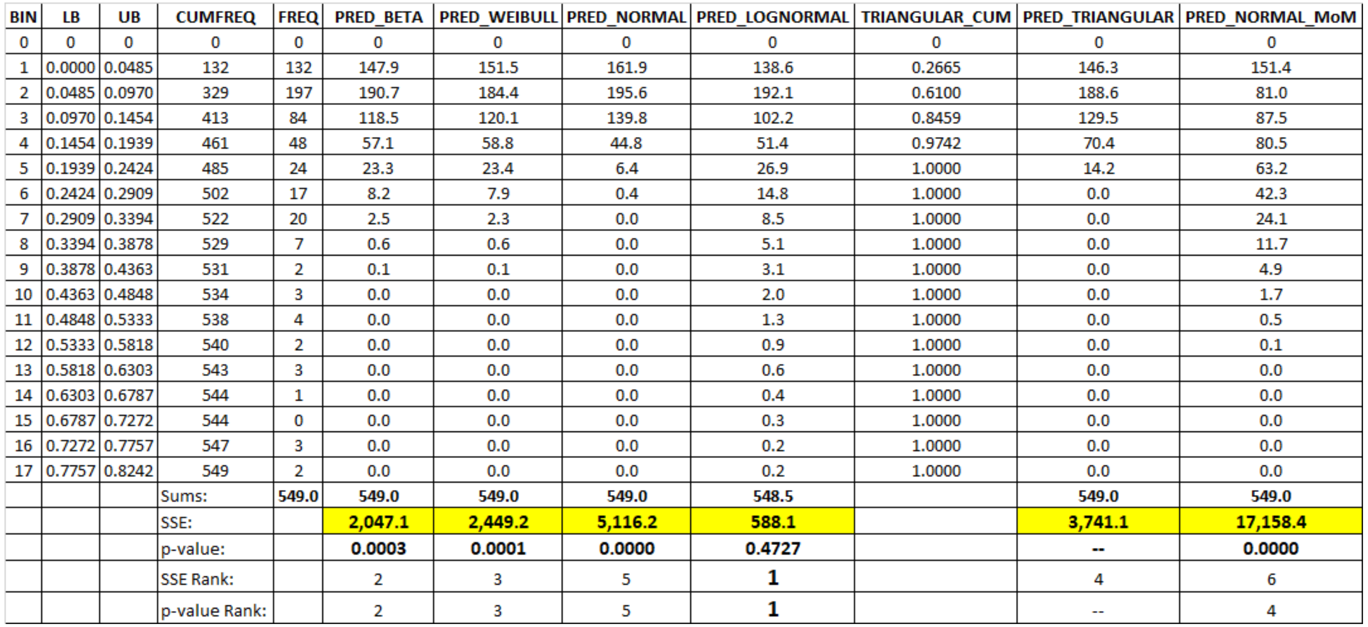
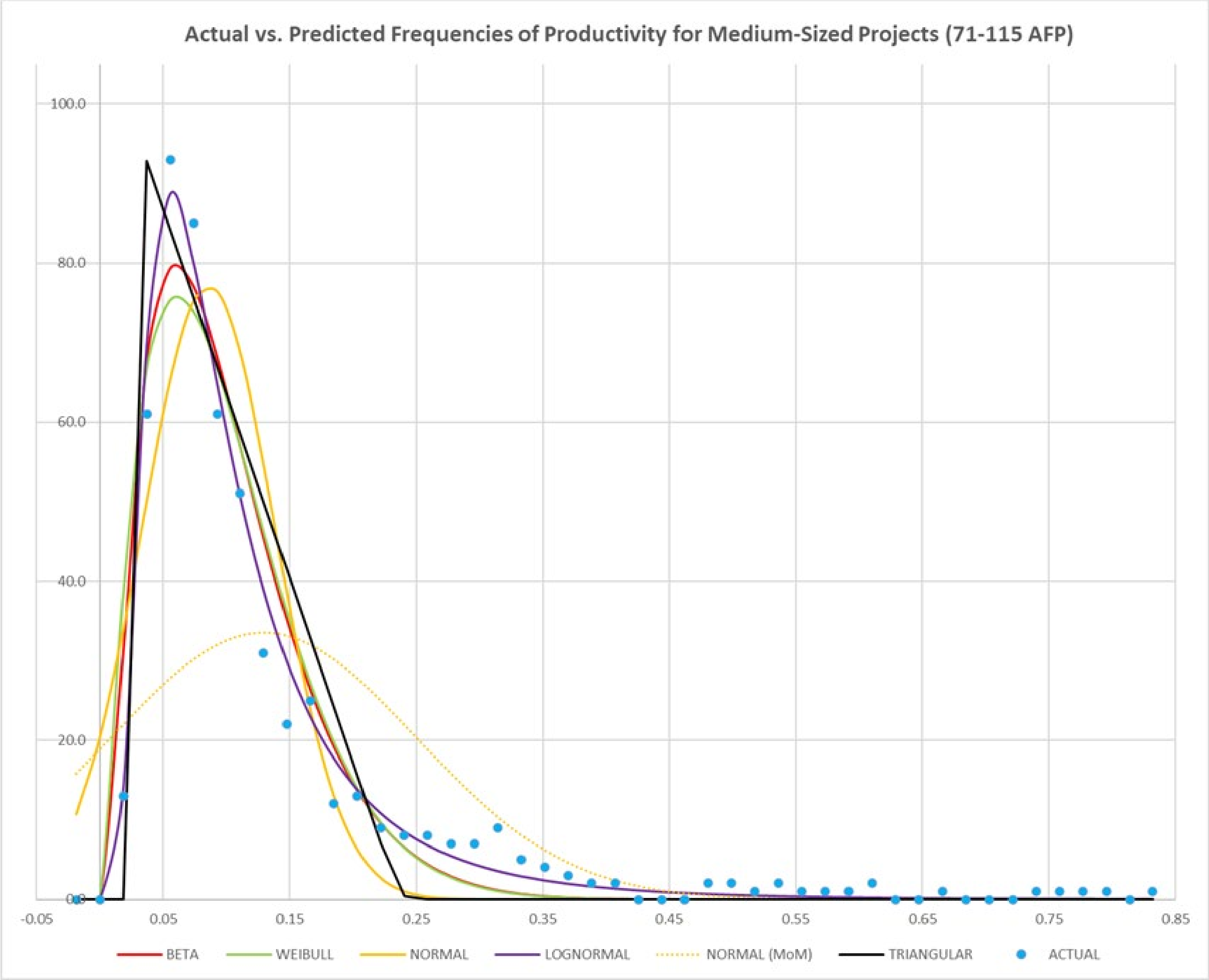


BIN	LB	UB	CUMFREQ	FREQ	PRED_BETA	PRED_WEIBULL	PRED_NORMAL	PRED_LOGNORMAL	TRIANGULAR_CUM	PRED_TRIANGULAR	PRED_NORMAL_MoM
0	0	0	0	0	0	0	0	0	0	0	0
1	0.0000	0.0485	132	132	147.9	151.5	161.9	138.6	0.2665	146.3	151.4
2	0.0485	0.0970	329	197	190.7	184.4	195.6	192.1	0.6100	188.6	81.0
3	0.0970	0.1454	413	84	118.5	120.1	139.8	102.2	0.8459	129.5	87.5
4	0.1454	0.1939	461	48	57.1	58.8	44.8	51.4	0.9742	70.4	80.5
5	0.1939	0.2424	485	24	23.3	23.4	6.4	26.9	1.0000	14.2	63.2
6	0.2424	0.2909	502	17	8.2	7.9	0.4	14.8	1.0000	0.0	42.3
7	0.2909	0.3394	522	20	2.5	2.3	0.0	8.5	1.0000	0.0	24.1
8	0.3394	0.3878	529	7	0.6	0.6	0.0	5.1	1.0000	0.0	11.7
9	0.3878	0.4363	531	2	0.1	0.1	0.0	3.1	1.0000	0.0	4.9
10	0.4363	0.4848	534	3	0.0	0.0	0.0	2.0	1.0000	0.0	1.7
11	0.4848	0.5333	538	4	0.0	0.0	0.0	1.3	1.0000	0.0	0.5
12	0.5333	0.5818	540	2	0.0	0.0	0.0	0.9	1.0000	0.0	0.1
13	0.5818	0.6303	543	3	0.0	0.0	0.0	0.6	1.0000	0.0	0.0
14	0.6303	0.6787	544	1	0.0	0.0	0.0	0.4	1.0000	0.0	0.0
15	0.6787	0.7272	544	0	0.0	0.0	0.0	0.3	1.0000	0.0	0.0
16	0.7272	0.7757	547	3	0.0	0.0	0.0	0.2	1.0000	0.0	0.0
17	0.7757	0.8242	549	2	0.0	0.0	0.0	0.2	1.0000	0.0	0.0
			Sums:	**549.0**	**549.0**	**549.0**	**549.0**	**548.5**		**549.0**	**549.0**
			SSE:		**2,047.1**	**2,449.2**	**5,116.2**	**588.1**		**3,741.1**	**17,158.4**
			p-value:		**0.0003**	**0.0001**	**0.0000**	**0.4727**		**--**	**0.0000**
			SSE Rank:		2	3	5	**1**		4	6
			p-value Rank:		2	3	5	**1**		--	4

Medium Project Productivity by “Microbin”

- All distributions tested, and fitted by minimizing sum of squared errors (SSE), using Excel solver
- CDF and PDF graphics compare actuals (blue dots) against each curve
- Purple curve, representing the Lognormal, appears to be the best fit



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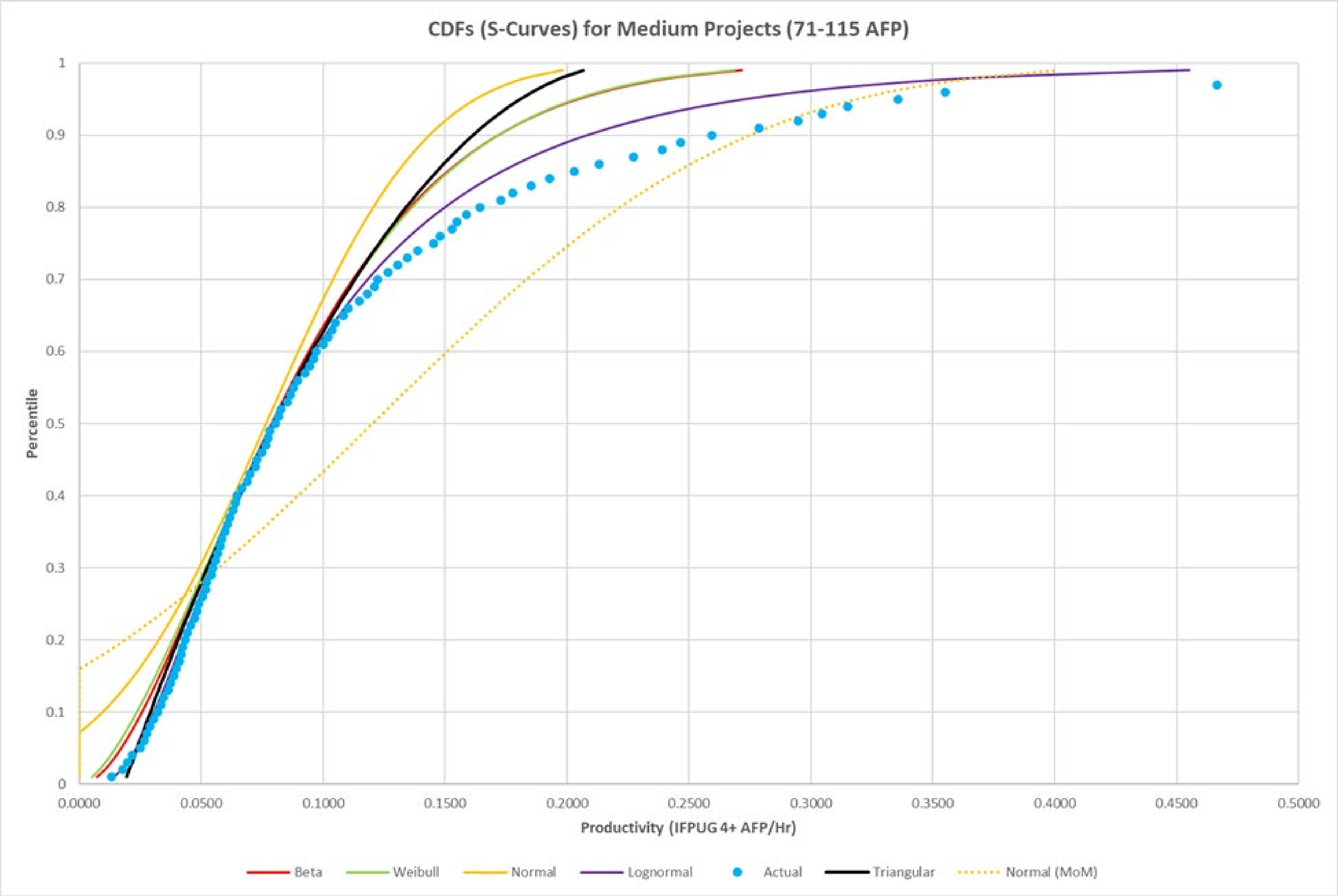

Large Projects

- Large projects have size > 115 AFP. 549 data points, roughly 1/3 of our dataset
- Highly right-skewed distribution
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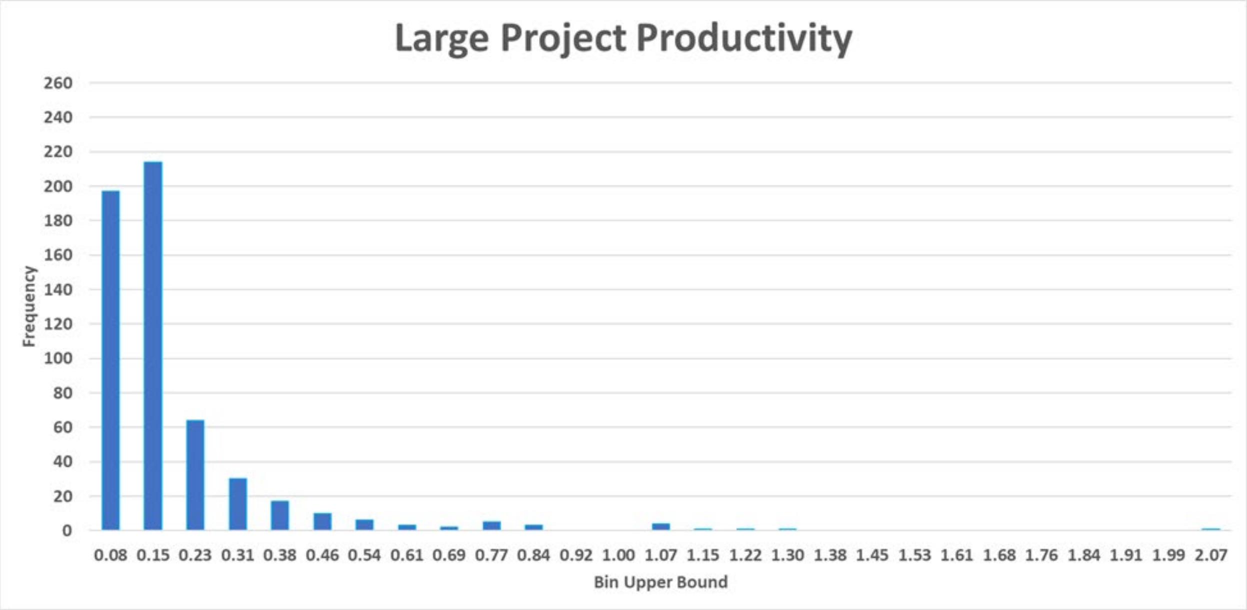
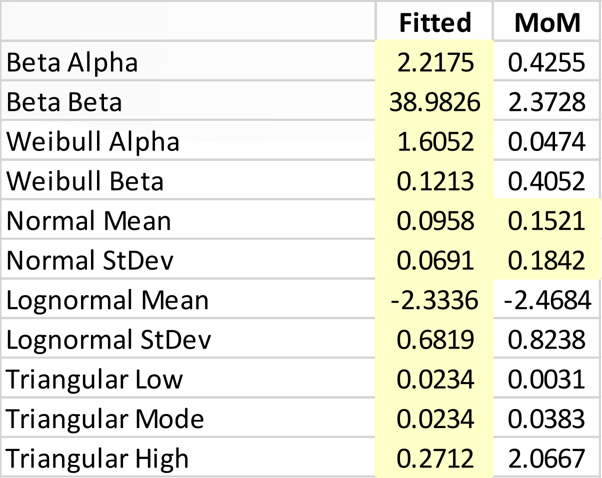
  - Suggests normal may not be the best fitting distribution
- High CV (121%) suggests high variability and uncertainty



Statistic	Size	Effort	Productivity
Mean	236.8	2,804	0.1521
Median	185.0	1,882	0.0988
StDev	171.4	2,609	0.1842
Skewness	0.906	1.060	0.868
CV	72%	93%	121%
Min	116	60	0.0130
Max	2,048	17,444	2.0667

Large Project Productivity Parameters

- Fitted parameters for each distribution are shown in the first table
- Method of Moments (MoM) is calculated by assuming the parameters of the data (e.g. mean and StDev) are the same as the parameters of the distribution



	Fitted	MoM
Beta Alpha	2.2175	0.4255
Beta Beta	38.9826	2.3728
Weibull Alpha	1.6052	0.0474
Weibull Beta	0.1213	0.4052
Normal Mean	0.0958	0.1521
Normal StDev	0.0691	0.1842
Lognormal Mean	-2.3336	-2.4684
Lognormal StDev	0.6819	0.8238
Triangular Low	0.0234	0.0031
Triangular Mode	0.0234	0.0383
Triangular High	0.2712	2.0667

- Second chart shows SSE and p-values for each distribution
  - Lowest SSE is the best fitting
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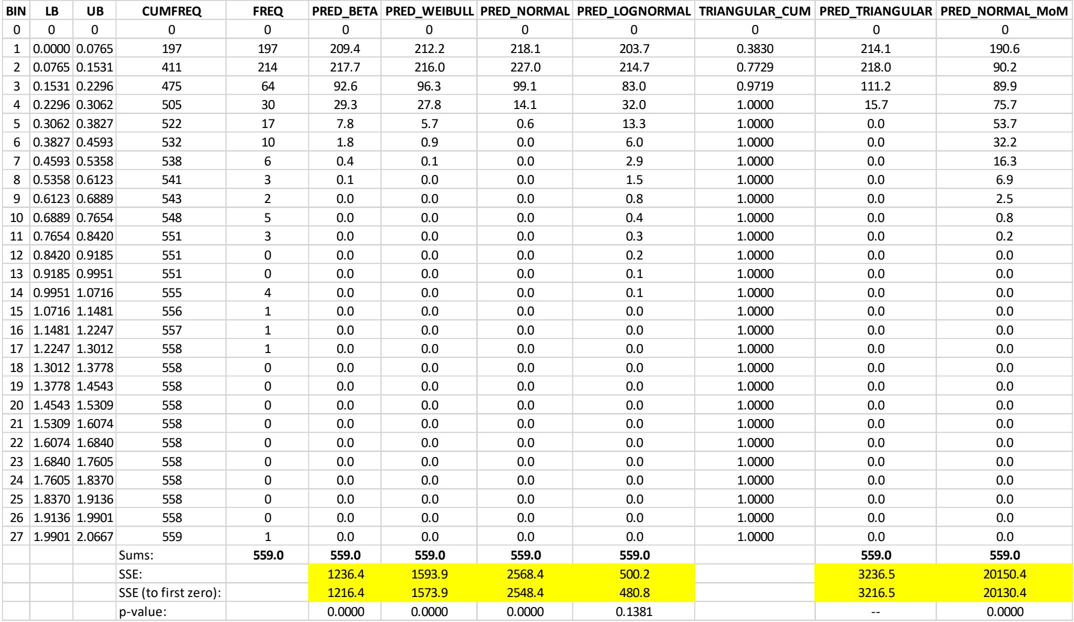
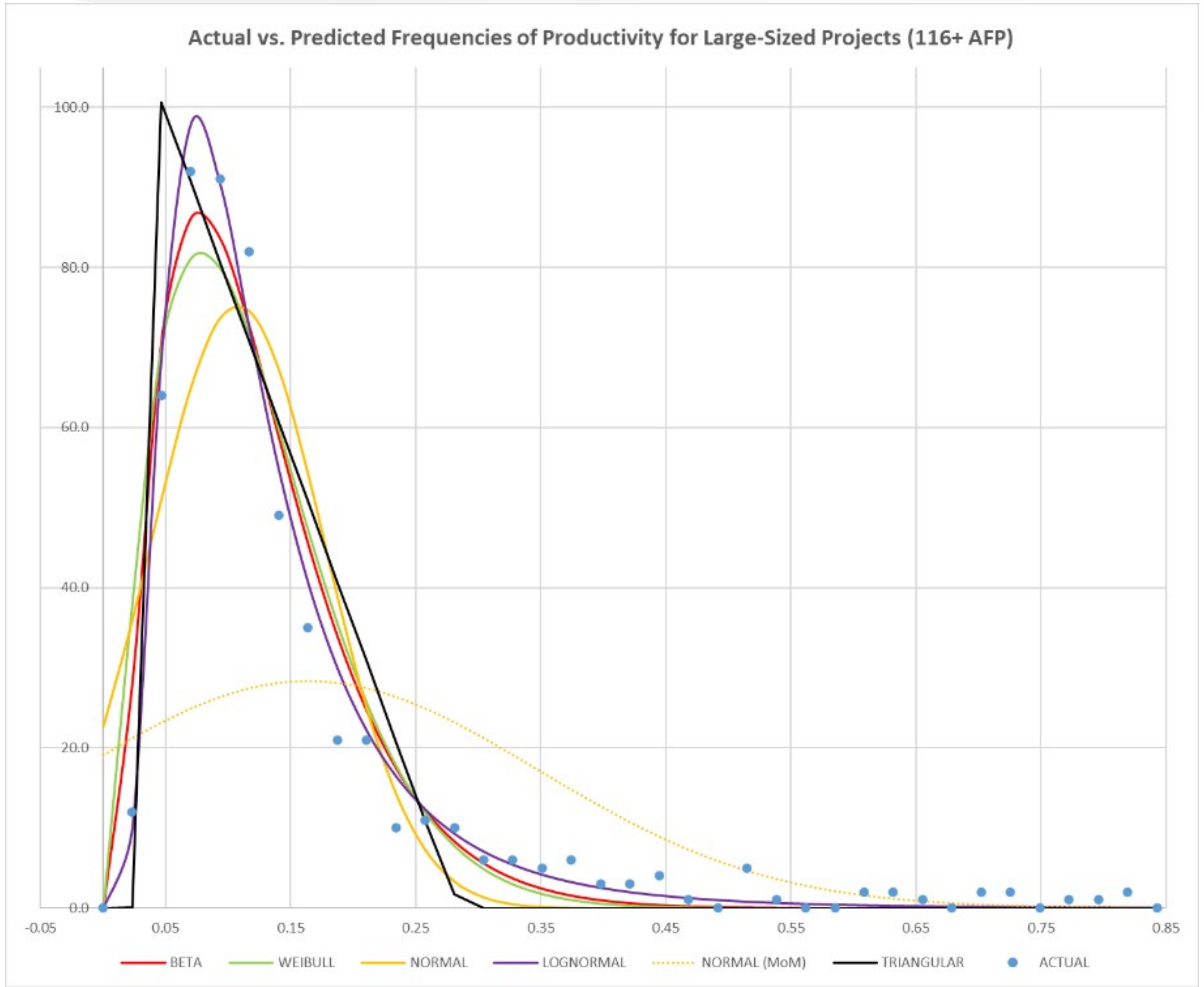
- Lognormal is best SSE and p-value
  - Significantly better than the 2nd and 3rd best, which is Beta and Weibull



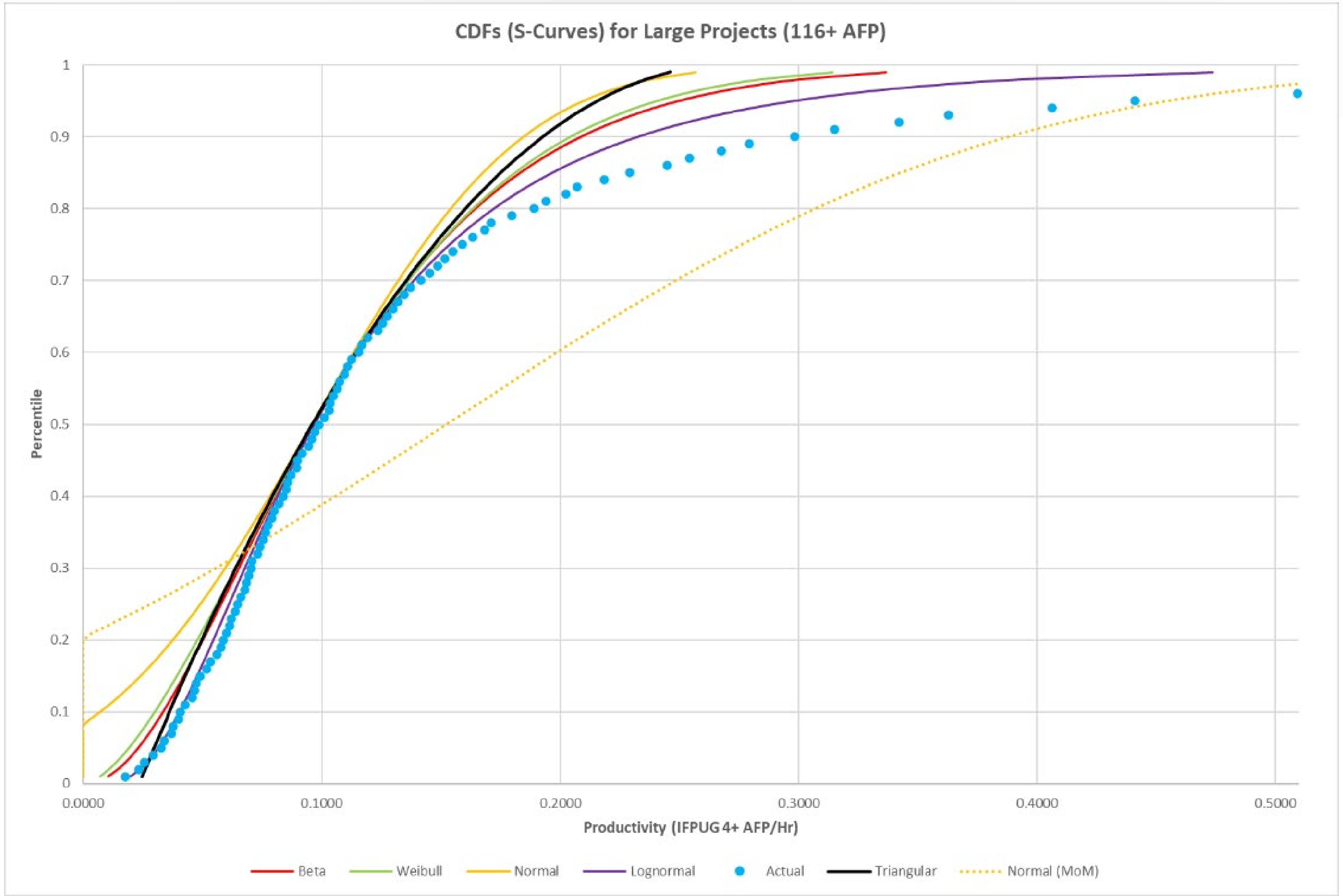
BIN	LB	UB	CUMFREQ	FREQ	PRED_BETA	PRED_WEIBULL	PRED_NORMAL	PRED_LOGNORMAL	TRIANGULAR_CUM	PRED_TRIANGULAR	PRED_NORMAL_MoM
0	0	0	0	0	0	0	0	0	0	0	0
1	0.0000	0.0765	197	197	209.4	212.2	218.1	203.7	0.3830	214.1	190.6
2	0.0765	0.1531	411	214	217.7	216.0	227.0	214.7	0.7729	218.0	90.2
3	0.1531	0.2296	475	64	92.6	96.3	99.1	83.0	0.9719	111.2	89.9
4	0.2296	0.3062	505	30	29.3	27.8	14.1	32.0	1.0000	15.7	75.7
5	0.3062	0.3827	522	17	7.8	5.7	0.6	13.3	1.0000	0.0	53.7
6	0.3827	0.4593	532	10	1.8	0.9	0.0	6.0	1.0000	0.0	32.2
7	0.4593	0.5358	538	6	0.4	0.1	0.0	2.9	1.0000	0.0	16.3
8	0.5358	0.6123	541	3	0.1	0.0	0.0	1.5	1.0000	0.0	6.9
9	0.6123	0.6889	543	2	0.0	0.0	0.0	0.8	1.0000	0.0	2.5
10	0.6889	0.7654	548	5	0.0	0.0	0.0	0.4	1.0000	0.0	0.8
11	0.7654	0.8420	551	3	0.0	0.0	0.0	0.3	1.0000	0.0	0.2
12	0.8420	0.9185	551	0	0.0	0.0	0.0	0.2	1.0000	0.0	0.0
13	0.9185	0.9951	551	0	0.0	0.0	0.0	0.1	1.0000	0.0	0.0
14	0.9951	1.0716	555	4	0.0	0.0	0.0	0.1	1.0000	0.0	0.0
15	1.0716	1.1481	556	1	0.0	0.0	0.0	0.0	1.0000	0.0	0.0
16	1.1481	1.2247	557	1	0.0	0.0	0.0	0.0	1.0000	0.0	0.0
17	1.2247	1.3012	558	1	0.0	0.0	0.0	0.0	1.0000	0.0	0.0
18	1.3012	1.3778	558	0	0.0	0.0	0.0	0.0	1.0000	0.0	0.0
19	1.3778	1.4543	558	0	0.0	0.0	0.0	0.0	1.0000	0.0	0.0
20	1.4543	1.5309	558	0	0.0	0.0	0.0	0.0	1.0000	0.0	0.0
21	1.5309	1.6074	558	0	0.0	0.0	0.0	0.0	1.0000	0.0	0.0
22	1.6074	1.6840	558	0	0.0	0.0	0.0	0.0	1.0000	0.0	0.0
23	1.6840	1.7605	558	0	0.0	0.0	0.0	0.0	1.0000	0.0	0.0
24	1.7605	1.8370	558	0	0.0	0.0	0.0	0.0	1.0000	0.0	0.0
25	1.8370	1.9136	558	0	0.0	0.0	0.0	0.0	1.0000	0.0	0.0
26	1.9136	1.9901	558	0	0.0	0.0	0.0	0.0	1.0000	0.0	0.0
27	1.9901	2.0667	559	1	0.0	0.0	0.0	0.0	1.0000	0.0	0.0
			Sums:	**559.0**	**559.0**	**559.0**	**559.0**	**559.0**		**559.0**	**559.0**
			SSE:		1236.4	1593.9	2568.4	500.2		3236.5	20150.4
			SSE (to first zero):		1216.4	1573.9	2548.4	480.8		3216.5	20130.4
			p-value:		0.0000	0.0000	0.0000	0.1381		--	0.0000

Large Project Productivity by “Microbin”

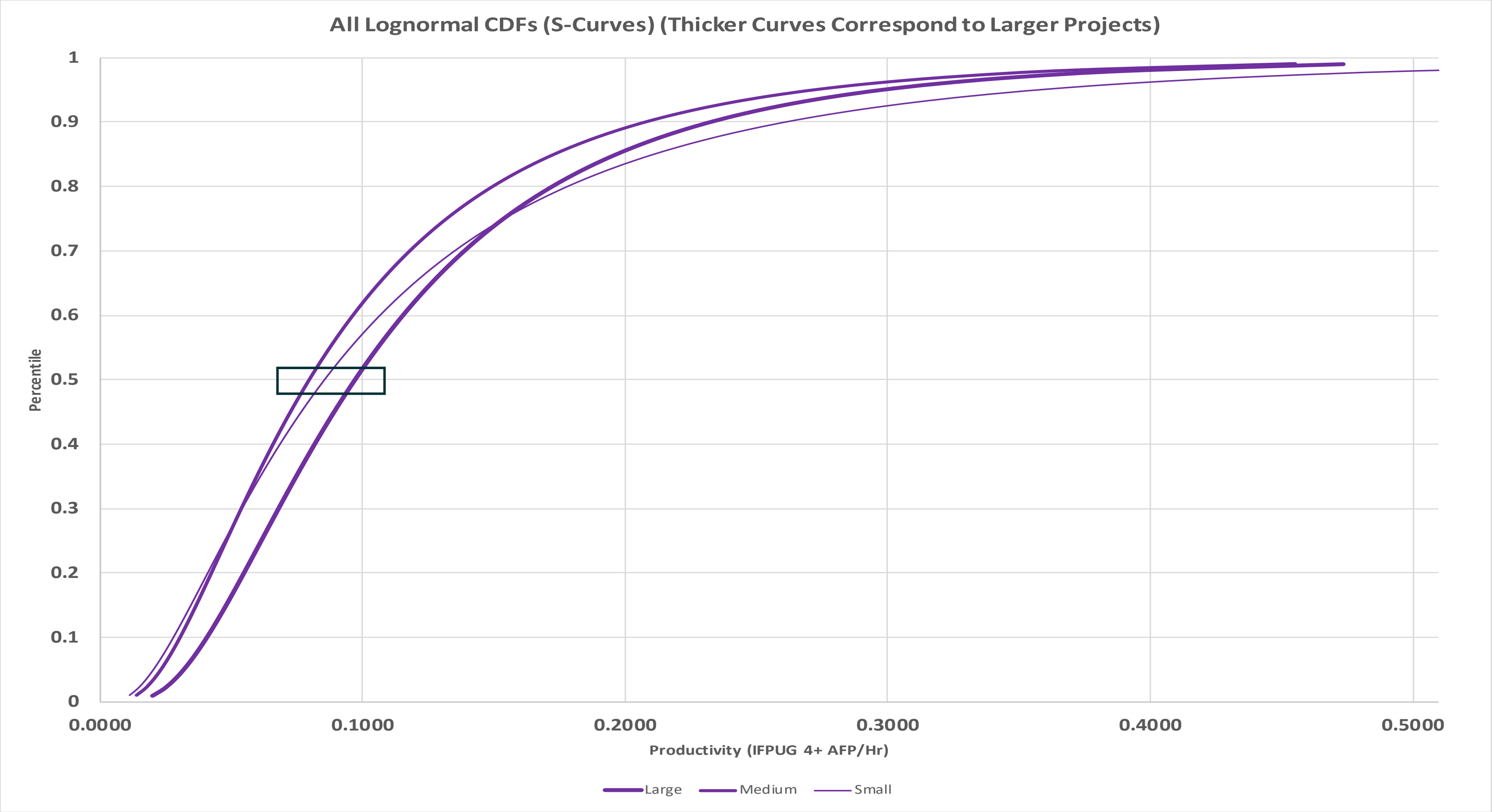
- All distributions tested, and fitted by minimizing sum of squared errors (SSE), using Excel solver
- CDF and PDF graphics compare actuals (blue dots) against each curve
- Purple curve, representing the Lognormal, appears to be the best fit



Large Project Productivity Fitted S-Curves



All Fitted CDFs (S-Curves), by Size of Project



The range of productivities in our data set is roughly 0 to 2 AFP/Hour.
But the median fitted productivity value never exceeds **0.1** AFP/Hour!

Practical Applications

- Scenario 1: Agile development project
  - Schedule and team size are constrained, resulting in a ***given effort*** variable
  - Effort is 1,100 person-hours, which is near the median of our dataset
  - Productivity is important because all the risk and uncertainty will come from productivity

Traditional estimation method:

- Calculate an average productivity from ISBSG
- Adjust for risk by varying productivity by plus/minus 10%

Result:

- Size estimate of 151 AFP, ranging from 136 to 166 AFP

Our method:

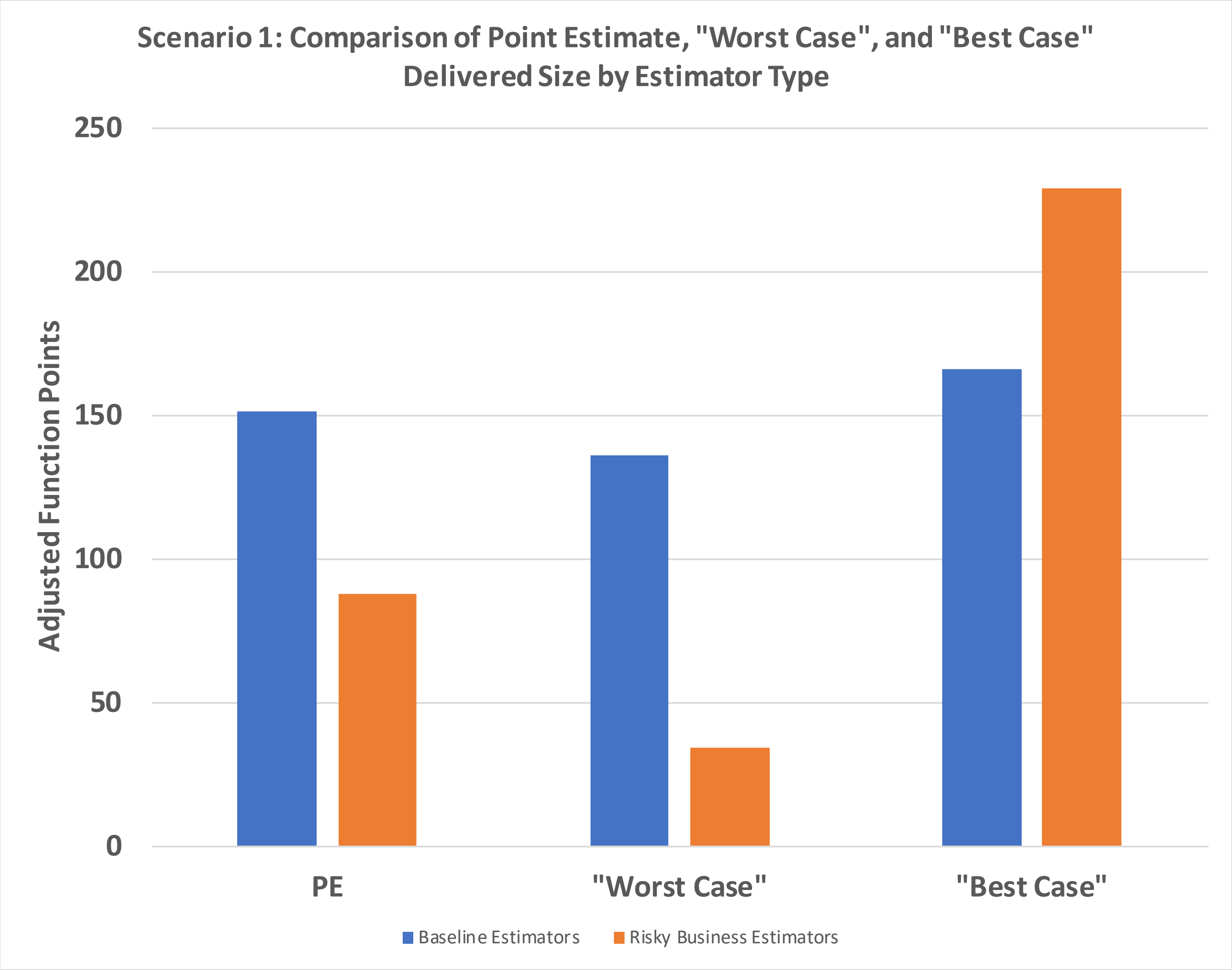
- Use Lognormal distribution from our Medium dataset, which has mean = -2.5275 and StDev = 0.7483
- Use Excel LOGNORM.INV to calculate 10% median and mean productivity

Result:

- Size estimate of 88 AFP, ranging from 34 to 229 AFP

- **Vastly different results!**
- **Not only is less code likely to be delivered (88 versus 151 AFP), but the risk is much worse**
- **Traditional method has over-estimated delivered results, and under-estimated risk**

Scenario 1: Traditional Estimators are Overly Optimistic and Understate Uncertainty About Delivered Size



Practical Applications

- Scenario 2: Estimate for a large program
  - Typical DoD acquisition programs are much larger than the median ISBSG project
  - Adjusted functional size assumed to be 1,500 AFP (99.9% percentile of ISBSG)

Traditional estimation method:

- Use a published source for productivity, based on project size[1] (16.29 FP/PM)
- Convert to FP/MH, and divide size by assumed productivity
- Adjust for risk by varying productivity by plus/minus 10%

Result:

- Effort estimate of 14,733 person-hours, ranging from 13,250 to 16,206 person-hours

Our method:

- Use Lognormal distribution from our Large dataset, which has mean = -2.3336 and StDev = 0.6819
- Use Excel LOGNORM.INV to calculate 10% median and mean productivity

Result:

- Effort estimate of 15,472 person-hours, ranging from 6,457 to 37,075 person-hours

- **Similar point estimates, but much different risk ranges**
- **Traditional method has under-estimated risk**
- **Worst case scenario is 2x more effort, resulting in 2x more cost!**

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[1] Beckett, Donald, *An Analysis of Function Point Trends*, https://www.qsm.com/articles/analysis-function-point-trends

Practical Applications

- Scenario 3: Productivity is “known”
  - Productivity is calculated based on analogous, agency-specific actuals
  - Size estimated at 1,100 person-hours, productivity assumed to be 0.07 AFP/MH

Traditional estimation method:

- Divide size by productivity

Result:

- Effort estimate of 15,714 person-hours
- All risk and uncertainty must be derived from the size estimate

Our method:

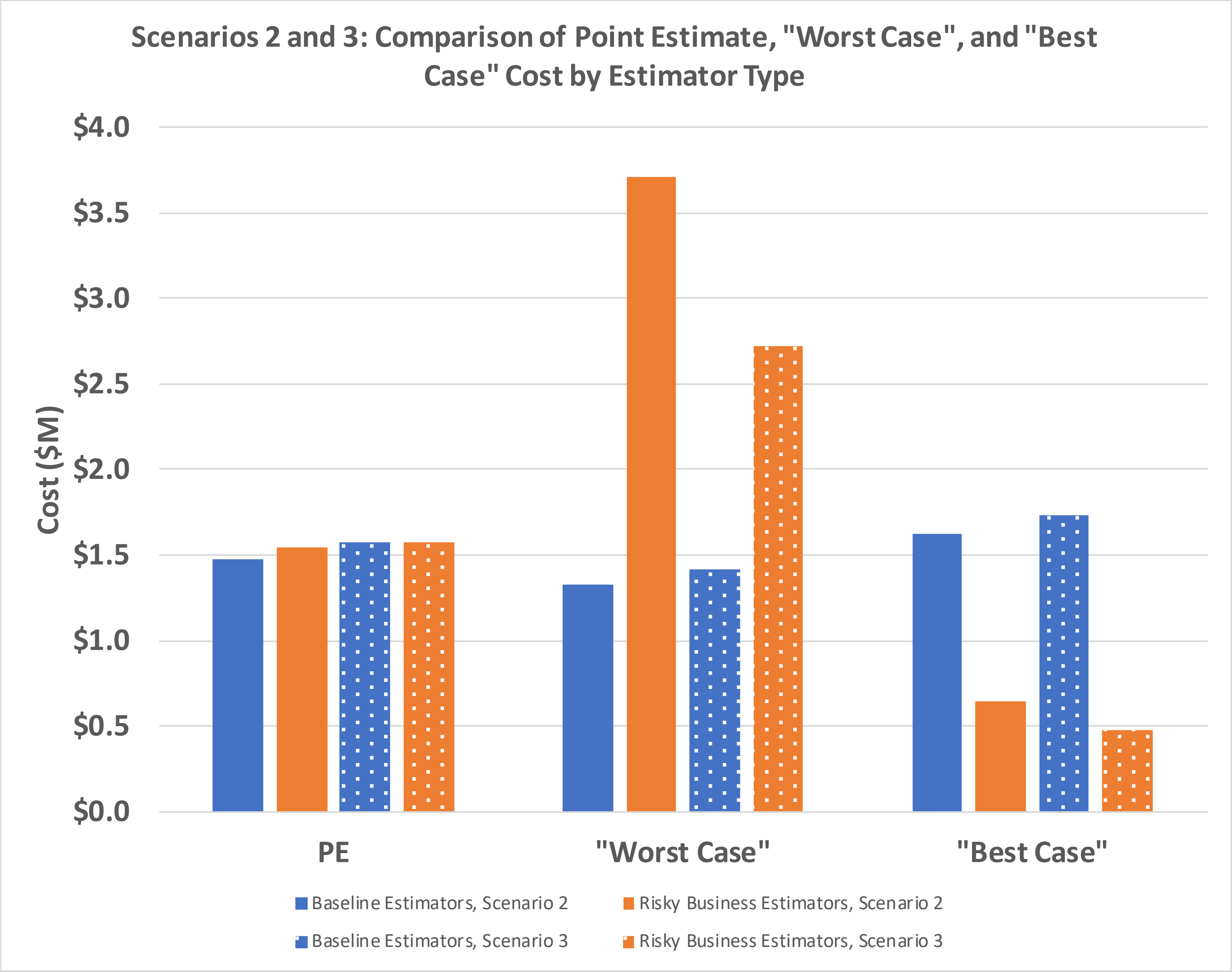
- Use Lognormal distribution from our Large dataset, which has mean = -2.3336 and StDev = 0.6819
- Use Excel LOGNORM.DIST to calculate a confidence level for the given productivity

Result:

- Productivity is at the 32nd percentile
- Using results from the 10th and 90th percentile results in a range of 4,735 to 27,188 person-hours

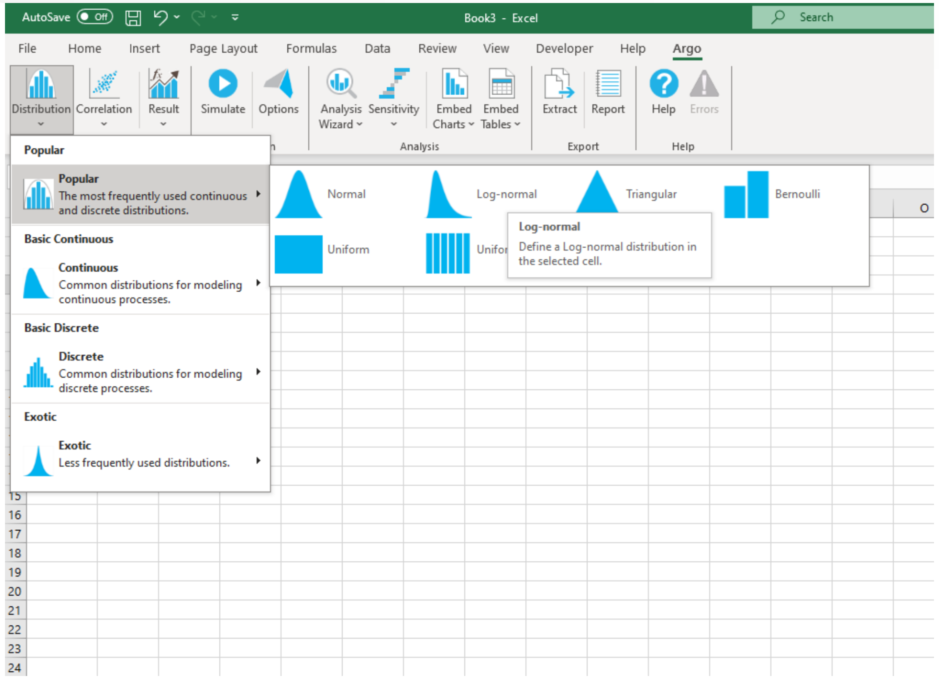
- **We have given context to the point estimate (32nd percentile)**
- **We have a suggested risk range, which was calculated without the need for Monte Carlo**

Scenarios 2&3: Traditional Estimators Understate Uncertainty About Cost



Practical Applications

- Scenario 4: Using Our Results within a Monte Carlo Simulation
  - All cost model inputs must have a specified distribution
  - Our results can be directly entered into the Monte Carlo simulation, by using the Lognormal distribution, with mean and standard deviation based on small medium or large size



- Choosing the right distribution and parameters is the key part of any Monte Carlo simulation
- Our results make that easy for the productivity parameter

Practical Applications

- Scenario 5: Productivity as an output
  - The COCOMO II equation does not require direct input of productivity. But it can be calculated based on size / effort.
  - Assume KESLOC of 200 and E and EM factors that result in effort = 225,175 person-hours[1]
  - Productivity calculated at 0.8882 SLOC/MH

Our method:

- Backfire to AFP/MH
  - Convert productivity from SLOC/MH to AFP/MH using a backfiring table[2]
  - Apply the Lognormal distribution, with mean and standard deviation based on small medium or large size
- **Or**, use the CV from one of our Lognormal distributions, and specify a distribution based on mean = calculated productivity and our CV
  - CV is unitless, so it is useful when you need a portable distribution
- Apply the derived distribution to the resulting effort

Result:

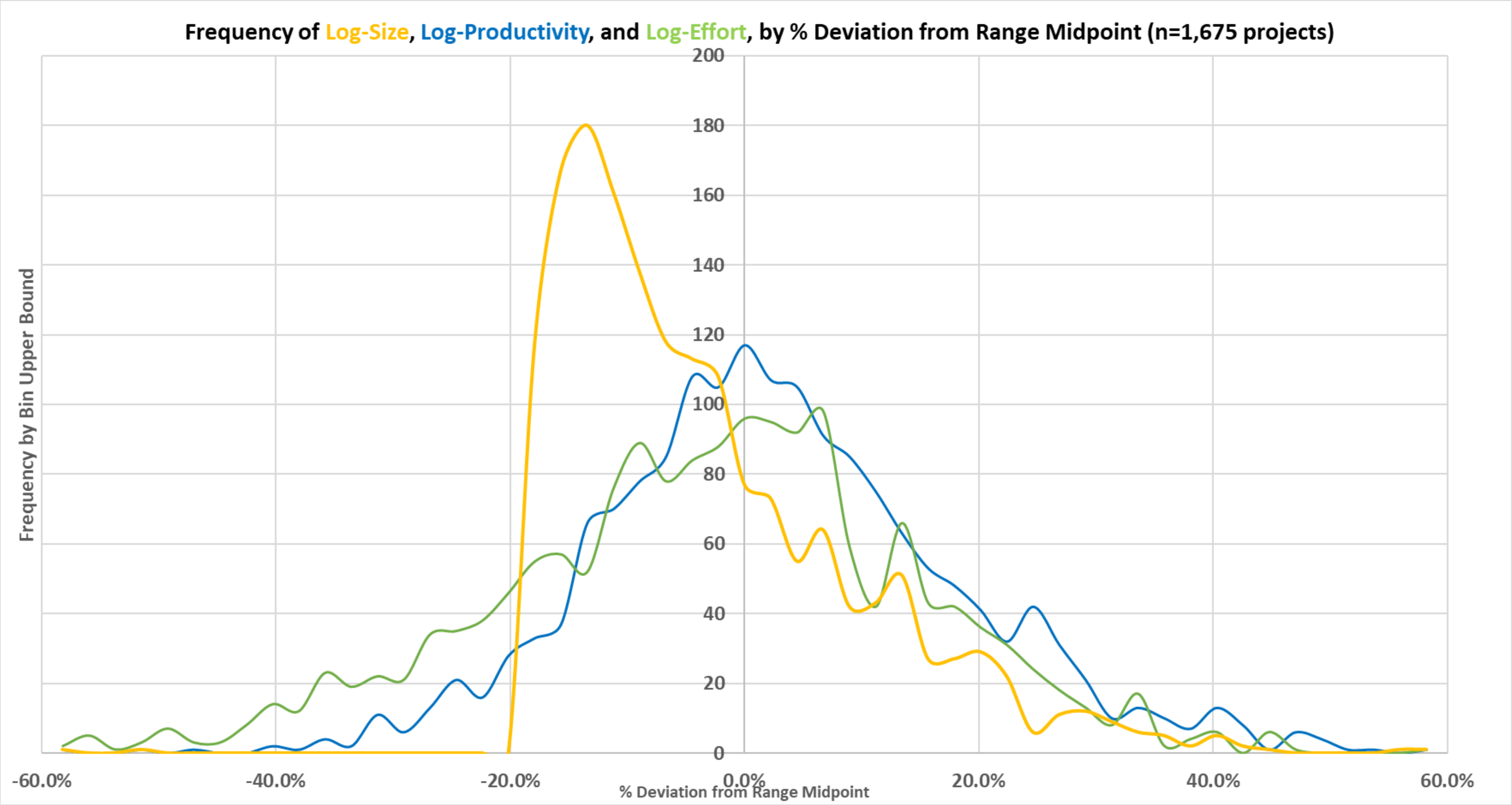
- Productivity can be properly risk-adjusted even though it was never directly specified as an input

---

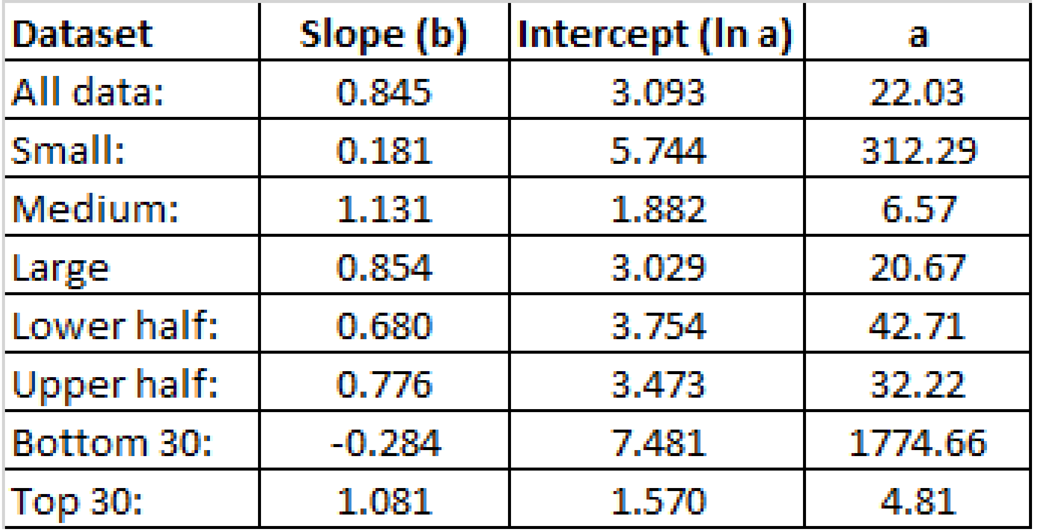
[1] CEBoK-S, Lesson 4 has a detailed walkthrough of an estimate built using this method

[2] QSM Function Point Languages Table, https://www.qsm.com/resources/function-point-languages-table

Additional Observation: Logs of Effort and Productivity Appear Normal



Additional Observation: EoS/CRS/DoS Varies by Size



Dataset	Slope (b)	Intercept (ln a)	a
All data:	0.845	3.093	22.03
Small:	0.181	5.744	312.29
Medium:	1.131	1.882	6.57
Large	0.854	3.029	20.67
Lower half:	0.680	3.754	42.71
Upper half:	0.776	3.473	32.22
Bottom 30:	-0.284	7.481	1774.66
Top 30:	1.081	1.570	4.81

“Scale” exponents range from **-0.284** (extreme EoS for smallest 30 projects) **1.081** (largest 30 projects), suggesting that the scale exponent could itself vary by size. This is consistent with most major economics textbooks, which teach initial EoS, followed by CRS, then DoS.

Conclusions

- How much variance is present in software productivity?
  - Significant variance. CVs exceed 100%
- What probability distribution should be used for productivity?
  - Lognormal!
- What are the best fitting parameters for the Lognormal distribution?
  - Based on the size category of Small, Medium, and Large:

Size Category	AFP Range	Number of Projects(n)	Best Fitting Curve	Curve Parameters
Small	0 to 70	567	Lognormal	Mean: -2.4558 StDev: 0.8729
Medium	71 to 115	549	Lognormal	Mean: -2.5275 StDev: 0.7483
Large	116+	559	Lognormal	Mean: -2.3336 StDev: 0.6819

- MS Excel LOGNORM.INV and LOGNORM.DIST can be used to create quick results, without the need for Monte Carlo

Next Steps

- Economy of Scale and Diseconomy of Scale are worth further exploration
  - ISBSG data suggests EoS for small projects and DoS for large projects
- Bucketing the data based on characteristics other than size
  - Agile versus waterfall development methodology
  - Programming language / environment
  - Industry
  - Government versus private sector
- Analysis using size measures other than AFP (e.g., SLOC)
- Analysis using other datasets (e.g., DoD CADE)

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Thank You!

Questions?

dbrown@technomics.net
571-366-1439

kcincotta@mitre.org
703-983-0184