COCOMO II Calibration

COCOMO Forum
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Outline

- **COCOMO II Calibration Approaches**
  - **Multiple Regression (COCOMO II.1997)**
  - **Bayesian Regression (COCOMO II.2000)**
  - **Comparison of the approaches**
- **Tailoring COCOMO II**
  - **Calibrating to existing project data**
  - **Consolidating or eliminating redundant parameters**
  - **Adding significant cost drivers not explicit in the model**
- **Ongoing and Future Research**
  - **Extensions of COCOMO II**

The Multiple Regression Approach

- **COCOMO II Post-Architecture Equation**

$$Effort = A \times [Size]^{1.01+\sum_{i=1}^{5} SF_i} \times \prod_{i=1}^{17} EM_i$$

Where

A = Multiplicative Constant

Size = Size of the software project measured in terms of KSLOC (thousands of Source Lines of Code) or Function Points and programming language.

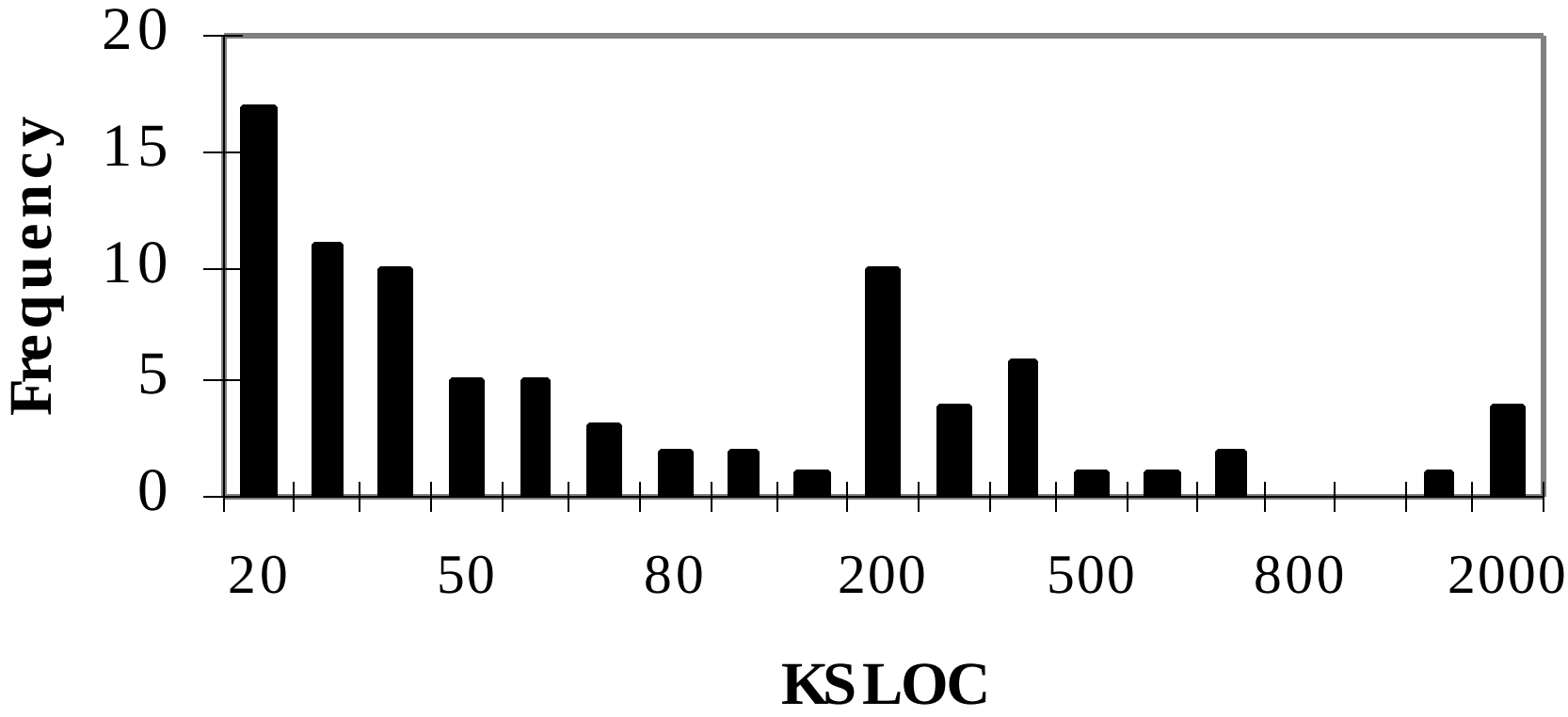
SF = Scale Factor

EM = Effort Multiplier

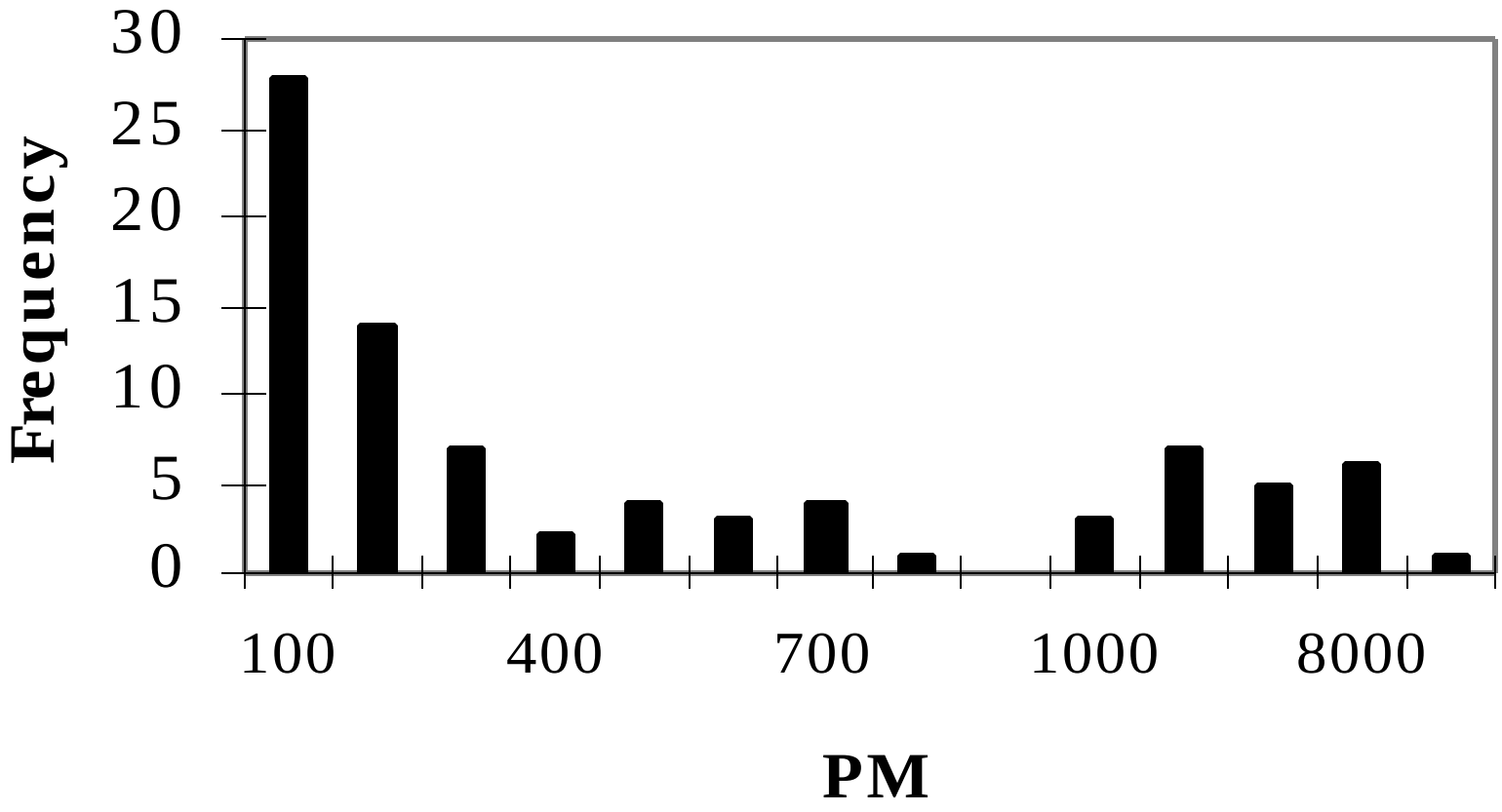
- **Linearizing (log-transformed model)**

$$ln(PM) = b_0 + b_1 \cdot 1.01 \cdot ln(Size) + b_2 \cdot SF_1 \cdot ln(Size) + \cdots + b_6 \cdot SF_5 \cdot ln(Size) + b_7 \cdot ln(EM_1) + b_8 \cdot ln(EM_2) + \cdots + b_{22} \cdot ln(EM_{16}) + b_{23} \cdot ln(EM_{17})$$

Distribution of Size (83 datapoints)



Distribution of Effort (83 datapoints)



Consolidated Highly Correlated Parameters

TIME	1.0000	**0.6860**	-0.2855	-0.2015
STOR	**0.6860**	1.0000	-0.0769	-0.0027
ACAP	-0.2855	-0.0769	1.0000	**0.7339**
PCAP	-0.2015	-0.0027	**0.7339**	1.0000
	TIME	**STOR**	**ACAP**	**PCAP**

- **What do we do? Þ Combine :**

TIME & STOR to give RCON (Resource Constraints)
ACAP & PCAP to give PERS (Personnel Factors)

Thus, 15 effort multipliers instead of 17 for calibration

Regression Results

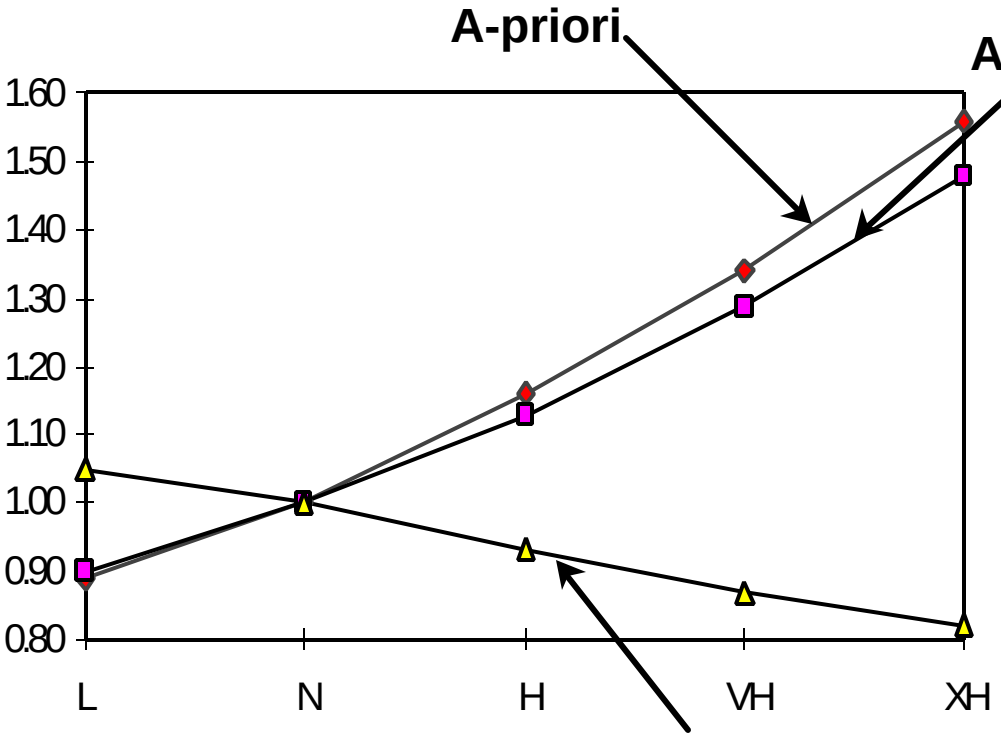
Data set = COCOMOII.1997
Response = log[PM] - 1.01*log[SIZE]
Coefficient Estimates

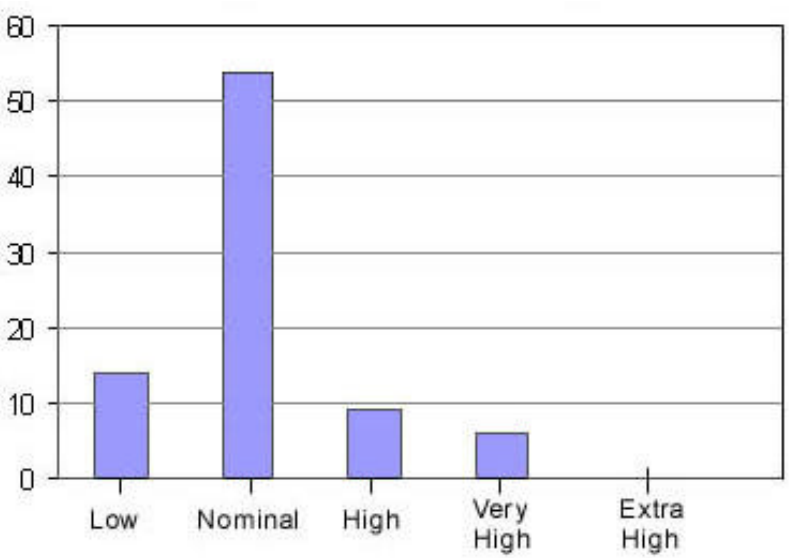
Label	Estimate	Std. Error	t-value
Constant_A	0.701883	0.231930	3.026
PMAT*log[SIZE]	0.000884288	0.0130658	0.068
PREC*log[SIZE]	**-0.00901971**	**0.0145235**	**-0.621**
TEAM*log[SIZE]	0.00866128	0.0170206	0.509
FLEX*log[SIZE]	0.0314220	0.0151538	2.074
RESL*log[SIZE]	**-0.00558590**	**0.019035**	**-0.293**
log[PERS]	0.987472	0.230583	4.282
log[RELY]	0.798808	0.528549	1.511
log[CPLX]	1.13191	0.434550	2.605
log[RCON]	1.36588	0.273141	5.001
log[PEXP]	0.696906	0.527474	1.321
log[LTEX]	**-0.0421480**	**0.672890**	**-0.063**
log[DATA]	2.52796	0.723645	3.493
log[RUSE]	**-0.444102**	**0.486480**	**-0.913**
log[DOCU]	**-1.32818**	**0.664557**	**-1.999**
log[PVOL]	0.858302	0.532544	1.612
log[AEXP]	0.560542	0.609259	0.920
log[PCON]	0.488392	0.322021	1.517
log[TOOL]	2.49512	1.11222	2.243
log[SITE]	1.39701	0.831993	1.679
log[SCED]	2.84074	0.774020	3.670

Counter-intuitive results shown in bold

COCOMO II.1997 Calibration

- **10% weighted average**
  - **Pragmatic approach to resolve for counter-intuitive results**





Develop for Reuse (RUSE)

COCOMO II.1997 Accuracy Results

Effort Prediction	Before Stratification By Organization	After Stratification By Organization
PRED(.20)	46%	49%
PRED(.25)	49%	55%
PRED(.30)	52%	64%

The Bayesian Regression Approach

$$g(b/y) = \frac{f(y/b)\,g(b)}{f(y)}$$

$$g(b/y) \; a \; l(b/y)\, g(b)$$

posterior information a **sample information X prior information**

A - Priori Information	+	Sampling Data	=	A - Posteriori Model

Prior Information

- 2-Round Delphi Approach
  - Determines Prior Means and Variances of Productivity Ranges (PRs)
  - Authors provide initial PR estimates
  - Experts provide their estimates
  - Authors summarize first round results
  - Experts get second chance to update their estimates
  - Second round results used as Prior Information

Example of Prior Information

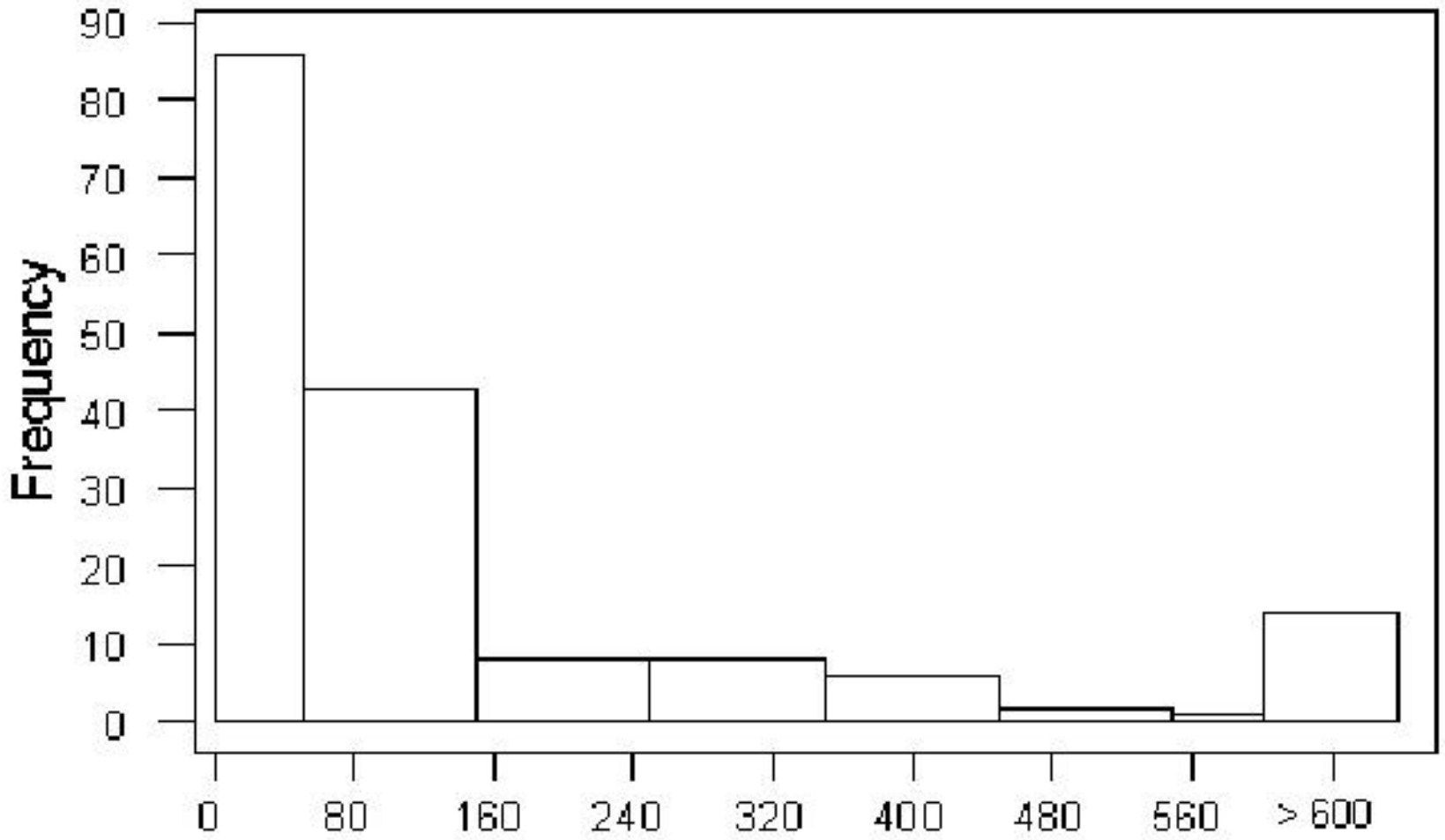
COCOMO II.2000 "A-Priori" Rating Scale for Develop for Reuse (RUSE)

Develop for Reuse (RUSE)	Productivity Range	Low (L)	Nominal (N)	High (H)	Very High (VH)	Extra High (XH)
Definition	Least Productive Rating / Most Productive Rating	None	Across project	Across program	Across product line	Across multiple product lines
2000 A-priori Values	Mean = 1.73 Variance = 0.05	0.89	1.0	1.15	1.33	1.54

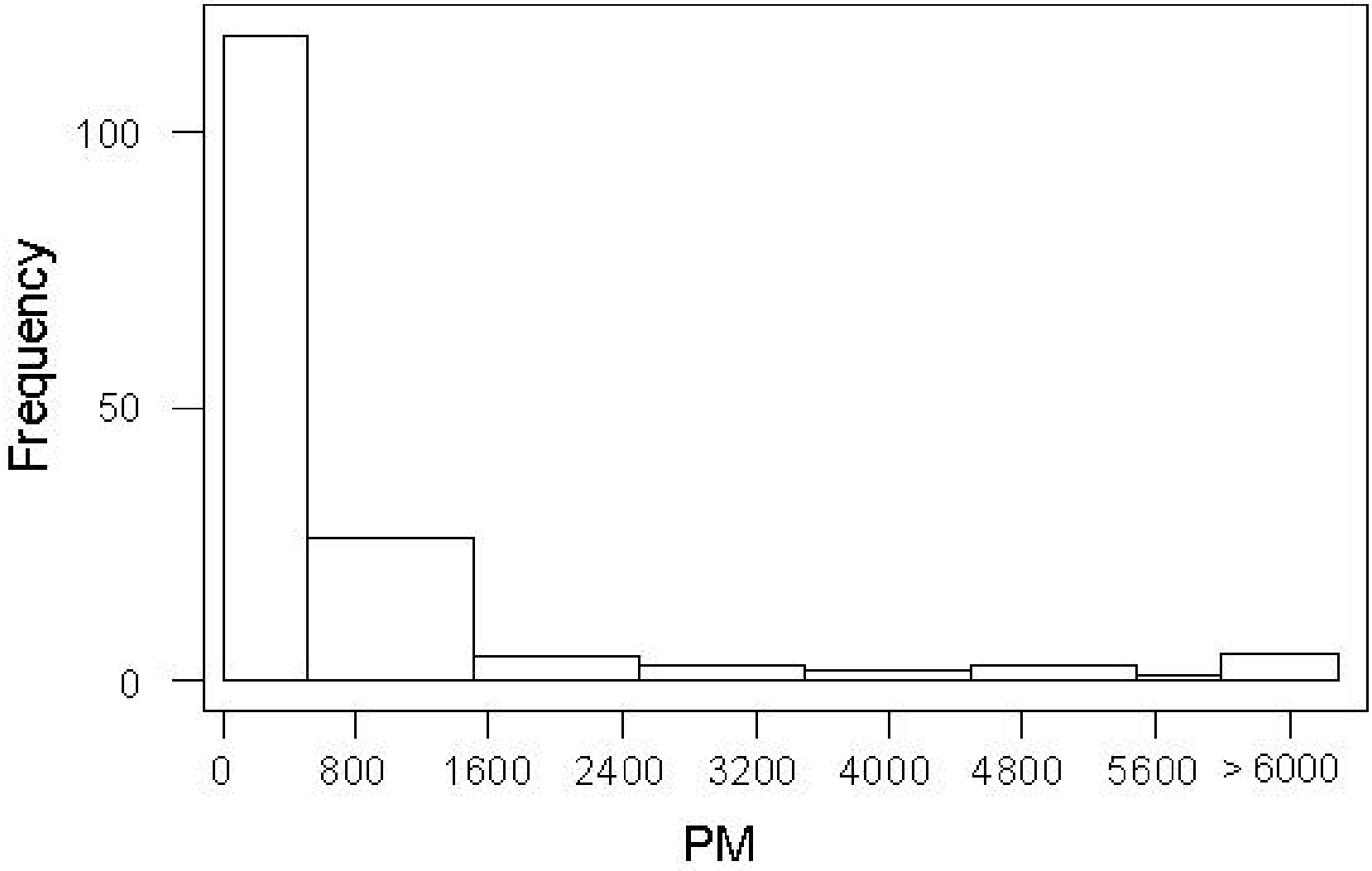
Sample Information

- Data collected on completed projects
- From Commercial, Aerospace, and FFRDC (Federally Funded Research and Development Center) sectors of software development - USC-CSE's affiliates
- 2000 dataset - 161 datapoints

Distribution of Size (161 datapoints)



Distribution of Effort (161 datapoints)



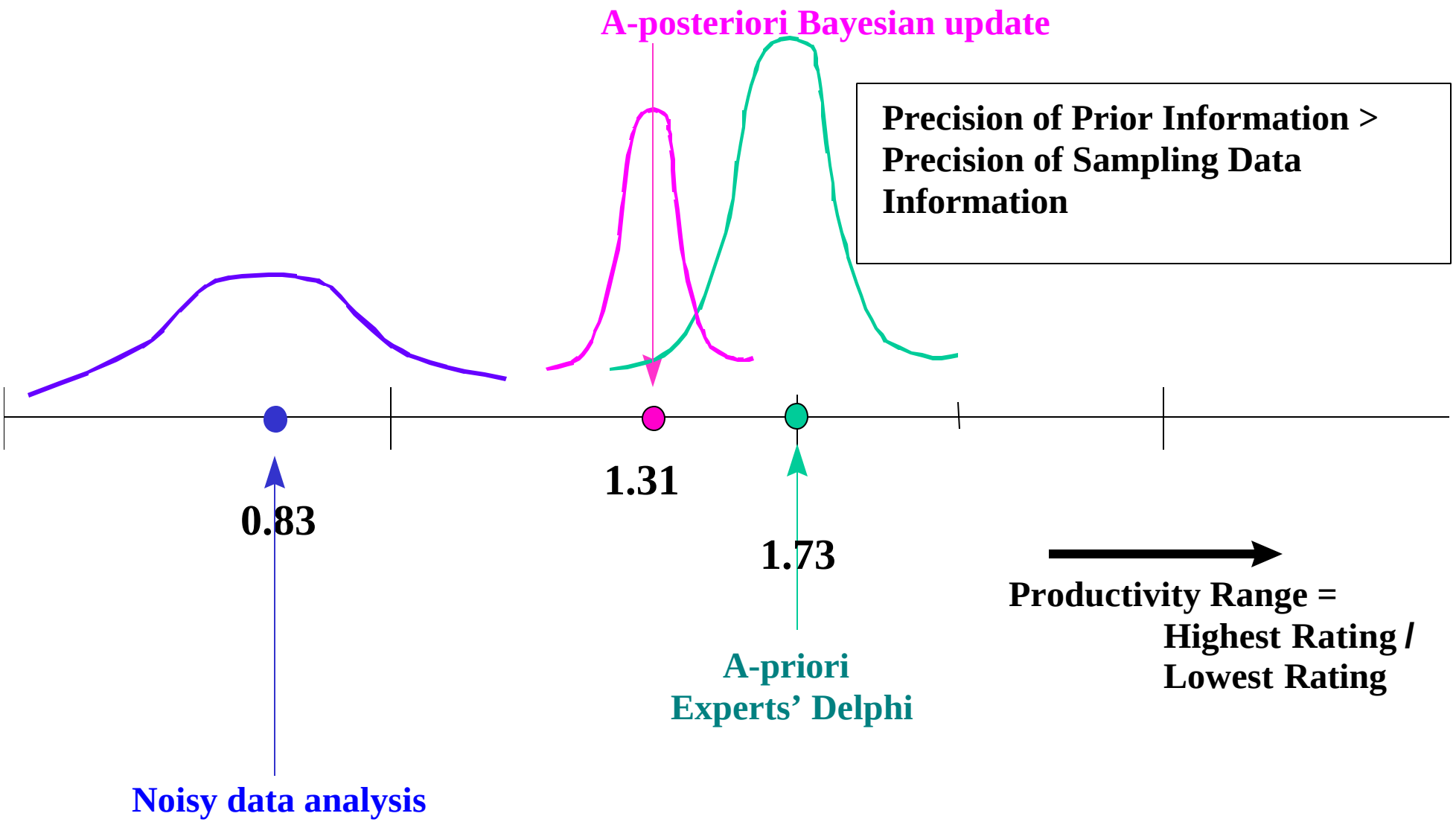
Sample Information Regression Results

Data set = COCOMOII.2000
Response = log[PM]
Coefficient Estimates

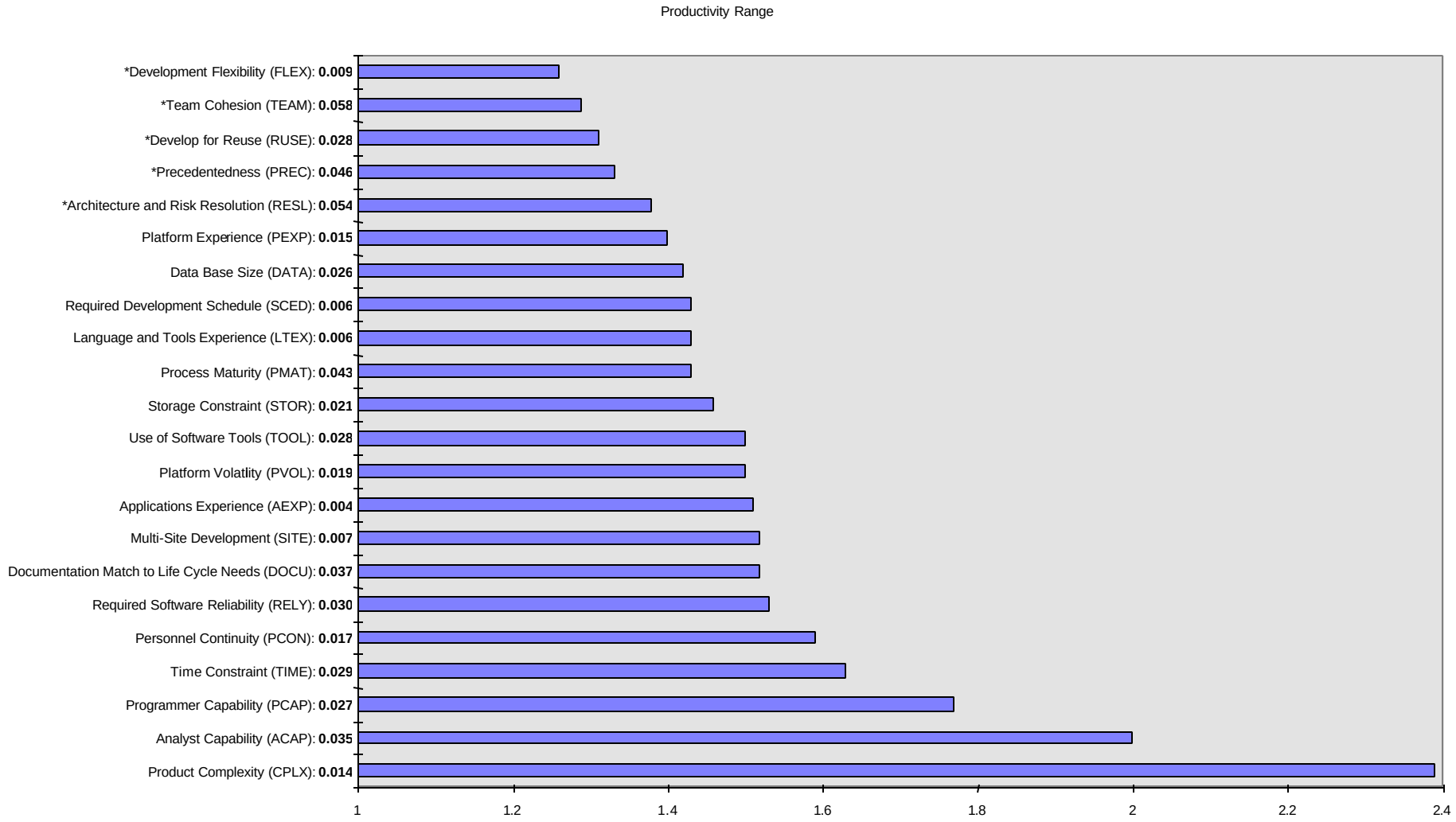
Label	Estimate	Std. Error	t-value
Constant_A	0.961552	0.103346	9.304
log[SIZE]	0.921827	0.0460578	20.015
PMAT*log[SIZE]	0.684836	0.481078	1.424
PREC*log[SIZE]	1.10203	0.373961	2.947
TEAM*log[SIZE]	0.323318	0.497475	0.650
FLEX*log[SIZE]	0.354658	0.686944	0.516
RESL*log[SIZE]	1.32890	0.637678	2.084
log[PCAP]	1.20332	0.307956	3.907
log[RELY]	0.641228	0.246435	2.602
log[CPLX]	1.03515	0.232735	4.448
log[TIME]	1.58101	0.385646	4.100
log[STOR]	0.784218	0.352459	2.225
log[ACAP]	0.926205	0.272413	3.400
log[PEXP]	0.755345	0.356509	2.119
log[LTEX]	0.171569	0.416269	0.412
log[DATA]	0.783232	0.218376	3.587
log[RUSE]	**-0.339964**	**0.286225**	**-1.188**
log[DOCU]	2.05772	0.622163	3.307
log[PVOL]	0.867162	0.227311	3.815
log[AEXP]	0.137859	0.330482	0.417
log[PCON]	0.488392	0.322021	1.517
log[TOOL]	0.551063	0.221514	2.488
log[SITE]	0.674702	0.498431	1.354
log[SCED]	1.11858	0.275329	4.063

Counter-intuitive results shown in bold

Posterior Information Example: RUSE



COCOMO II.2000 Bayesian Posteriori PRs



COCOMO II.2000 Parameter: Associated Variance

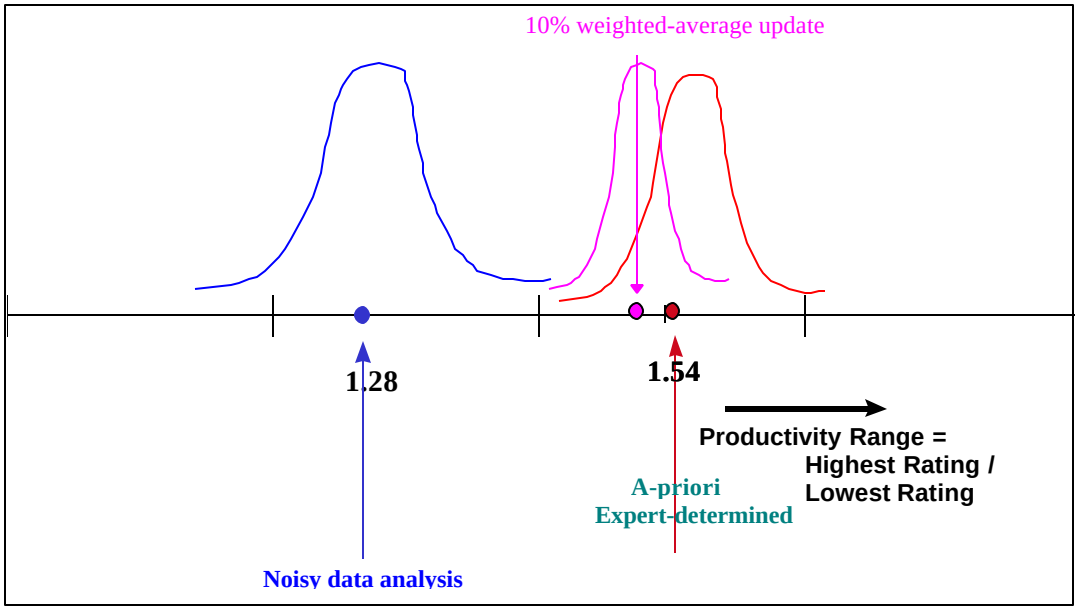
*** Scale Factor ranges based on 100 kSLOC Size**

COCOMO II.2000 Accuracy Results

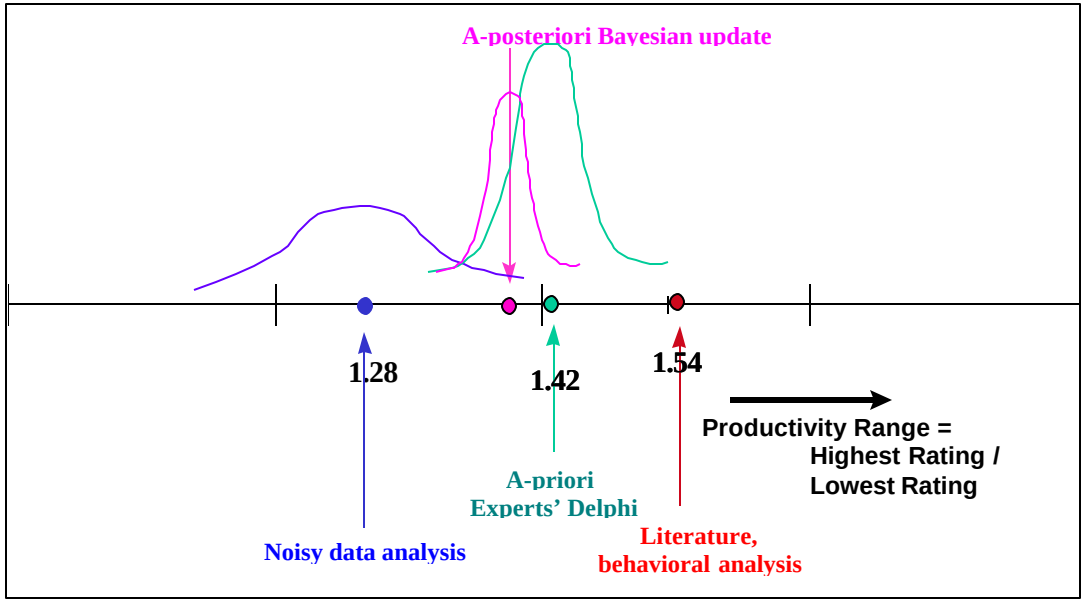
Effort Prediction	Before Stratification By Organization	After Stratification By Organization
PRED(.20)	63%	70%
PRED(.25)	68%	76%
PRED(.30)	75%	80%

COCOMO II Calibration Approaches

COCOMO II.1997 10% weighed-average approach



Bayesian approach - weight determined by data and prior significance



Comparison

Prediction Accuracy	Calibrated Using 83 datapoints					
	Pure-Regression Based Model (Model A)		COCOMO II.1997 - 10% Weighted-Average Based Model (Model B)		Bayesian Approach Based Model (Model C)	
	Number of datapoints used to validated					
	83	161	83	161	83	161
PRED(.20)	49%	31%	46%	54%	41%	54%
PRED(.25)	63%	39%	49%	59%	53%	62%
PRED(.30)	64%	44%	52%	63%	58%	66%

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- ➡ Tailoring COCOMO II
  - Calibrating to existing project data
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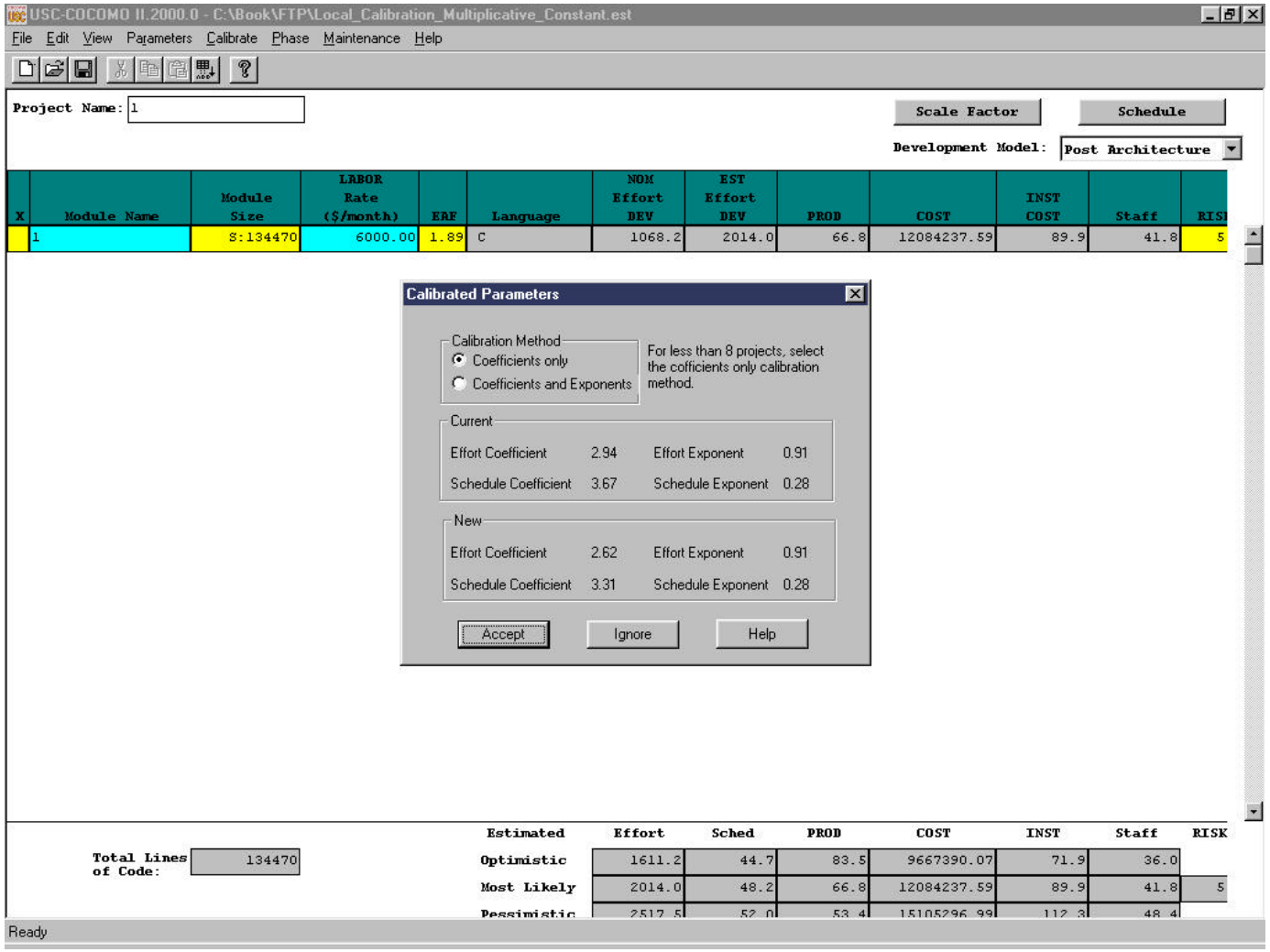
- Ongoing and Future Research
  - Extensions of COCOMO II

Calibrating to existing project data

Project Number (i)	PM_i	$kSLOC_i$	$\tilde{O}EM_i$	$å SF_i$	$Effort_i$
1	1854.55	134.47	1.89	29.28	2014.04
2	258.51	132	0.49	16.72	278.777
3	201.00	44.03	1.06	22.48	227.996
4	58.87	3.57	5.05	18.19	59.56684
5	9661.02	380.8	3.05	26.77	9819.961
6	7021.28	980	0.92	25.21	8092.762
7	91.67	11.186	2.45	23.5	114.2832
8	689.66	61.56	2.38	26.48	886.2177

Calibrating Multiplicative Constant



Accuracy after Calibrating Multiplicative Constant

Project Number (I)	PM_i	$Effort_i$ Using COCOMO II.2000	Error Using COCOMO II.2000	$Effort_i$ Using Local A	Error Using Local A
1	1854.55	2014.04	0.09	1794.00	0.03
2	258.51	278.777	0.08	248.32	0.04
3	201.00	227.996	0.13	203.09	0.01
4	58.87	59.56684	0.01	53.06	0.10
5	9661.02	9819.961	0.02	8747.11	0.09
6	7021.28	8092.762	0.15	7208.61	0.03
7	91.67	114.2832	0.25	101.80	0.11
8	689.66	886.2177	0.29	789.40	0.14

Accuracy on COCOMO II.2000 data

Effort

COCOMO II.2000	Before Stratification by Organization	After Stratification by Organization
PRED(.20)	63%	70%
PRED(.25)	68%	76%
PRED(.30)	75%	80%

Schedule

COCOMO II.2000	Before Stratification by Organization	After Stratification by Organization
PRED (.20)	50%	50%
PRED (.25)	55%	67%
PRED (.30)	64%	75%

Consolidating or Eliminating Redundant Parameters

- **ACAP, PCAP => PERS**

Capability Scale	ACAP	PCAP	PERS = ACAP*PCAP
VL	1.42	1.34	1.90
L	1.19	1.15	1.37
N	1.0	1.0	1.0
H	0.85	0.88	0.75
VH	0.71	0.76	0.54

Adding Significant Cost Drivers

- Security – maybe add SCON for Security Constraints
- USC COCOMO II tool and Costar have facility to add cost drivers

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  - **Extensions of COCOMO II**

Extensions of COCOMO II using Bayesian Approach

- COQUALMO (Defect density prediction quality model)
- COCOTS (COTS Integration model)
- CORADMO (Rapid application development model)
- COPROMO (Productivity analysis model)
- COSSEMO (Staged schedule estimation model)
- Impact of (i) TOOL on Effort (ii) PMAT on Effort