École de gestion TELFER School of Management

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ADM 2304
APPLIED STATISTICAL METHODS IN BUSINESS

Final Exam – December 13, 2008

NAME (please print): _____

STUDENT NUMBER: _____

SECTION (please circle one): A B

Time allowed: **3 hours**
Question booklet: **10 pages (all single-sided sheets, including this cover sheet)**
Appendices: **7 pages of output and 5 tables (on 6 double-sided sheets)**

Instructions:

1. Calculators, rulers, and one sheet of notes (8.5 x 14 in.) are allowed.
2. Please write clearly and legibly.
3. ***Complete all hypothesis tests at the .05 level of significance unless otherwise indicated***.
4. You must hand everything back at the end of the exam (exam question booklet, appendices and stat-tables), but please keep your personal sheet of notes.

Question	Value	Mark
1	16	
2	11	
3	15	
4	25	
Total	**67**	

Statement of Academic Integrity

The School of Management does not condone academic fraud, an act by a student that may result in a false academic evaluation of that student or of another student. Without limiting the generality of this definition, academic fraud occurs when a student commits any of the following offences: plagiarism or cheating of any kind, use of books, notes, mathematical tables, dictionaries or other study aid unless an explicit written note to the contrary appears on the exam, to have in his/her possession cameras, radios (radios with head sets), tape recorders, pagers, cell phones, or any other communication device which has not been previously authorized in writing.

I have read the text on academic integrity and I pledge not to have committed or attempted to commit academic fraud in this examination.

Signed: _____

Question 1. [16 marks]

A Leger Marketing poll released on 4 December 2008 asked a random sample of Canadians whether they would choose an election or a coalition, if MPs were to vote non-confidence in the newly elected government led by Stephen Harper. The results were distributed as follows:

Region	Choice		
	Election	**Coalition**	**Undecided**
B.C.	73	39	23
Alberta	75	19	12
Prairies	35	17	8
Ontario	168	152	70
Quebec	60	139	41
Maritimes	19	29	13
Totals	430	395	167

(a) Calculate a 95% confidence interval for the proportion of Canadians who supported an election.

[3]

(b) Test whether there were more Canadians who supported an election than those who supported the coalition (ignore the undecided group).

[4]

(c) Test whether there was a difference in the proportions of British Columbians and of Ontarians who supported the coalition.

[4]

(d) Test whether the distribution of responses differed by region. Use the partial Minitab output below to minimize your calculations and start by filling in some of the blanks. What is the approximate p-value?

```
Expected counts are printed below observed counts
Chi-Square contributions are printed below expected counts

       C1     C2      C3     C4      C5     C6    Total

 1     73      75      35     168      60     19    430
    _____   45.95   26.01  169.05  104.03  26.44
    _____  18.370   3.109   0.007  18.637  2.094

 2     39      19      17     152     139     29    395
    _____   42.21   23.89  155.29   95.56  24.29
    _____  12.761   1.988   0.070  19.742  0.914

 3     23      12       8      70      41     13    167
    22.73   _____   10.10   65.66   40.40  _____
    0.003   _____   0.437   0.288   0.009  _____

Total    ___     ___     60     390     240     61    992

Chi-Sq = ______, DF = __, P-Value = _____
```

[5]

Question 2. [11 marks]

To compare the performance of two recently hired financial advisors, a financial planning firm selected a random sample of portfolios from each advisor and examined the one-year performance for each portfolio. The results are given below, with the analyses in Appendix A. (Your answers can be chosen from the tests listed in the output.)

Analyst1	Analyst2	Diff1-2
-32.5	-30.4	-2.1
-26.8	-31.5	4.7
-32.2	-31.5	-0.7
-31.1	-35.5	4.4
-33.3	-29.3	-4
-33.3	-29.3	-4
-28.2	-32.4	4.2
-31.8	-31.6	-0.2
-29.6	-31.6	2
-31.5	-33.1	1.6
-26.4	-33.7	7.3
-28.4	-28.6	0.2
-25.6	-34.8	9.2
-26.3	-37.3	11
-26.5	-33.1	6.6

(a) Are the two samples independent or paired? Explain briefly.

[1]

(b) Given your answer in (a), identify the appropriate test that should be completed to determine if there is a difference in average (mean/median) performance between the two advisors. Explain briefly with specific reference to the appropriate graph(s).

[2]

(c) Notwithstanding the above, calculate a 95% confidence interval to estimate the difference in mean performance between the two financial advisors.

[3]

(d) Using the results in (c), perform a hypothesis test to determine if there is a significant difference in performance.

[3]

(e) Explain briefly but completely why the corresponding non-parametric test would lead you to the same result as part (d).

[1]

(f) Explain briefly what the W statistic represents in the Mann-Whitney test

[1]

Question 3. [15 marks]

A manufacturer is interested in studying the effects of temperature and supplier on the hardness of windshields. He has four suppliers of raw materials for making the plastic windshields and produces the windshields using three different temperatures.

Temperature	SupplierA	SupplierB	SupplierC	SupplierD
Low	67	60	90	54
	77	55	87	67
	58	48	98	56
Medium	87	55	101	67
	78	67	98	87
	92	60	89	70
High	89	70	104	78
	92	82	98	79
	78	67	110	81

Appendix B contains the output for the analysis of variance.

```
Rows: Temperature   Columns: Supplier

               A      B       C      D    All

Low        67.33  54.33   91.67  59.00  68.08
               3      3       3      3     12

Medium     85.67  60.67   96.00  74.67  79.25
               3      3       3      3     12

High       86.33  73.00  104.00  79.33  85.67
               3      3       3      3     12

All        79.78  62.67   97.22  71.00  77.67
               9      9       9      9     36

Cell Contents:  Hardness  :  Mean
                           Count
```

(a) Draw the interactions plot (be sure to label everything properly).

[3]

(b) What does the plot show about how the factors affect the response?

[2]

(c) Comment on whether the model assumptions are warranted.

[2]

(d) Test whether the effect of temperature on hardness depends on the supplier.

[4]

(e) After deciding that the suppliers have an effect on the hardness of the windshields, you decide to compare Supplier C with the other suppliers. Calculate the appropriate margin of error that would allow you to make these comparisons. What do you conclude?

[4]

Question 4. [25 marks]

Appendix A contains the Minitab output for a regression analysis to explain the variation in total Profits ($millions) in 2007 among a sample of large multi-national companies using the following predictor variables:

Revenues ($ millions)
Assets ($ millions)
Equity ($millions)
Market Value ($ millions)
Employees

The complete data are listed after the second model.

(a) Examine the residual plot for Model 1 and discuss the appropriateness of the model assumptions.

[2]

(b) What might you do to improve the fit? How would you justify this if someone accused you of "playing around" with the data?

[2]

(c) How do we get from Model 1 to Model 2?

[2]

(d) Discuss three reasons why Model 2 is considered better than Model 1.

[3]

(e) Looking at the data and the output, what other data manipulations would you recommend? Explain briefly.

[2]

(f) Using Model 2, test at the **.01** level of significance the usefulness of Model 2 for predicting profits.

[3]

(g) Using Model 2, test at the **.01** level of significance the (marginal) usefulness of the Market Value variable for predicting Profits. State your conclusion as clearly as possible.

[3]

(h) What is the meaning of the value of the coefficient for the Market Value variable in Model 2?

[2]

(i) What is the 99% interval for the average profit of companies with revenues of $56,114, equity values of $14,920, market values of $102,932 (all figures in millions), and 152,000 employees? Be sure to indicate the units of measurement.

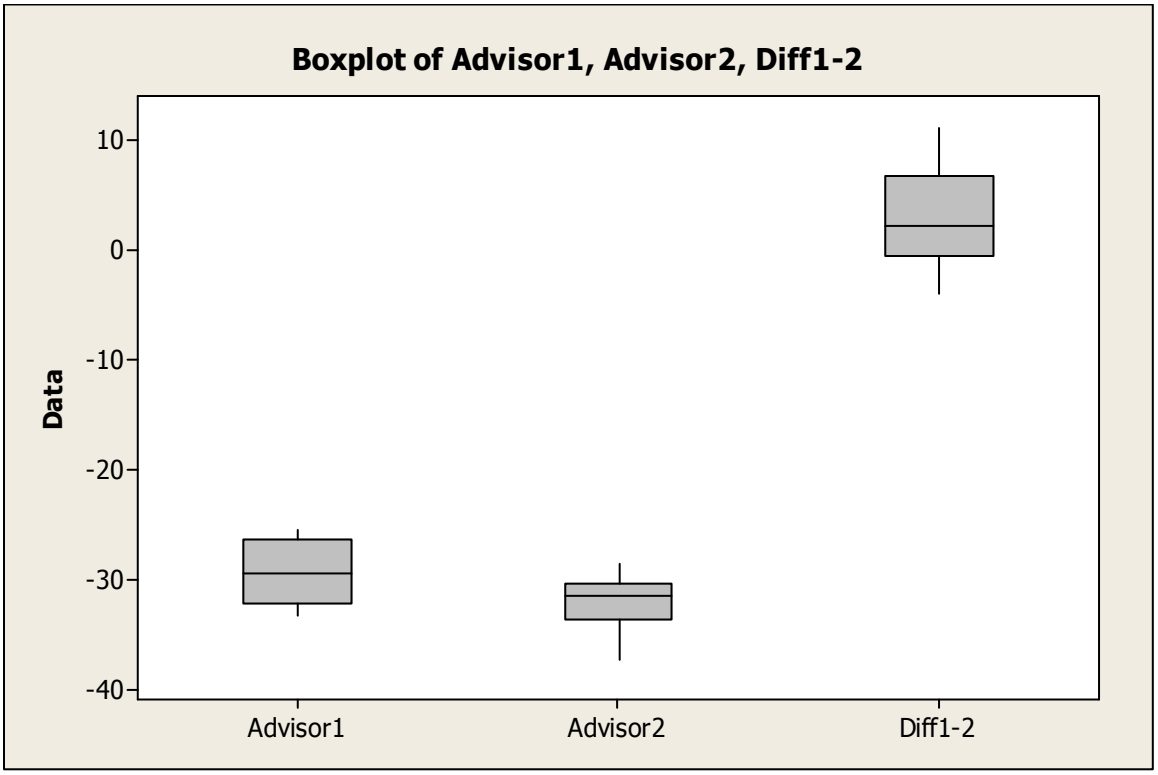
[3]

(j) What is the 99% interval for the actual profit for a company with the characteristics above? How do you interpret the fact that your interval does not contain the actual profit for company 13 which has the same characteristics?

[3]

Appendix A

Advisor1	Advisor2	Diff1-2
-32.5	-30.4	-2.1
-26.8	-31.5	4.7
-32.2	-31.5	-0.7
-31.1	-35.5	4.4
-33.3	-29.3	-4
-33.3	-29.3	-4
-28.2	-32.4	4.2
-31.8	-31.6	-0.2
-29.6	-31.6	2
-31.5	-33.1	1.6
-26.4	-33.7	7.3
-28.4	-28.6	0.2
-25.6	-34.8	9.2
-26.3	-37.3	11
-26.5	-33.1	6.6



Two-Sample T-Test and CI: Advisor1, Advisor2

```
Two-sample T for Advisor1 vs Advisor2

           N    Mean  StDev  SE Mean
Advisor1  15  -29.57   2.82     0.73
Advisor2  15  -32.25   2.42     0.63


Difference = mu (Advisor1) - mu (Advisor2)
Estimate for difference:  2.68000
95% CI for difference:  ____________________
T-Test of difference = 0 (vs not =): T-Value = ____  P-Value = _____  DF = __
Both use Pooled StDev = ______
```

Paired T-Test and CI: Advisor1, Advisor2

```
Paired T for Advisor1 - Advisor2

             N      Mean    StDev  SE Mean
Advisor1    15  -29.5667   2.8185   0.7277
Advisor2    15  -32.2467   2.4239   0.6259
Difference  15   2.68000  4.60887  1.19001


95% CI for mean difference: ____________________
T-Test of mean difference = 0 (vs not = 0): T-Value = ____  P-Value = _____
```

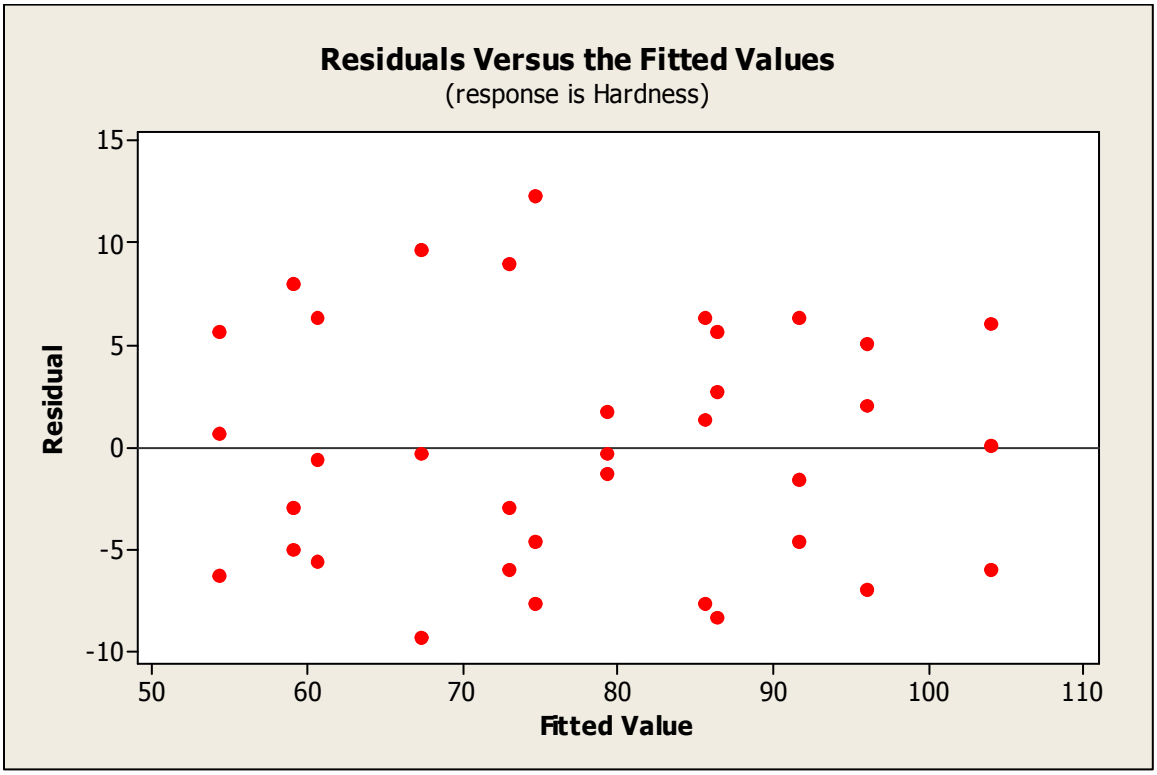
Mann-Whitney Test and CI: Advisor1, Advisor2

```
           N   Median
Advisor1  15  -29.600
Advisor2  15  -31.600


Point estimate for ETA1-ETA2 is 2.800
95.4 Percent CI for ETA1-ETA2 is _____________
W = 286.0
Test of ETA1 = ETA2 vs ETA1 not = ETA2 is significant at 0.0279
The test is significant at 0.0278 (adjusted for ties)
```

Wilcoxon Signed Rank Test: Diff1-2

```
Test of median = 0.000000 versus median not = 0.000000

               N
              for   Wilcoxon         Estimated
          N  Test  Statistic      P     Median
Diff1-2  15    15       94.5  0.053      2.600
```

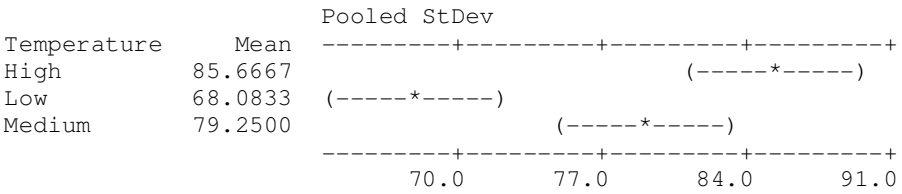
Appendix B

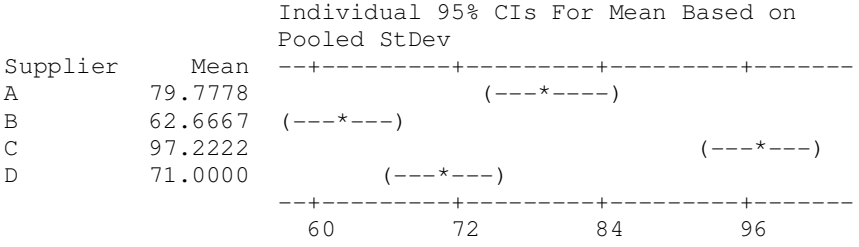


Two-way ANOVA: Hardness versus Temperature, Supplier

Source	DF	SS	MS	F	P
Temperature	2	1900.17	950.08	_____	_____
Supplier	3	5906.89	1968.96	_____	_____
Interaction	6	253.61	42.27	_____	_____
Error	24	1211.33	50.47		
Total	35	9272.00			

S = 7.104 R-Sq = 86.94% R-Sq(adj) = 80.95%

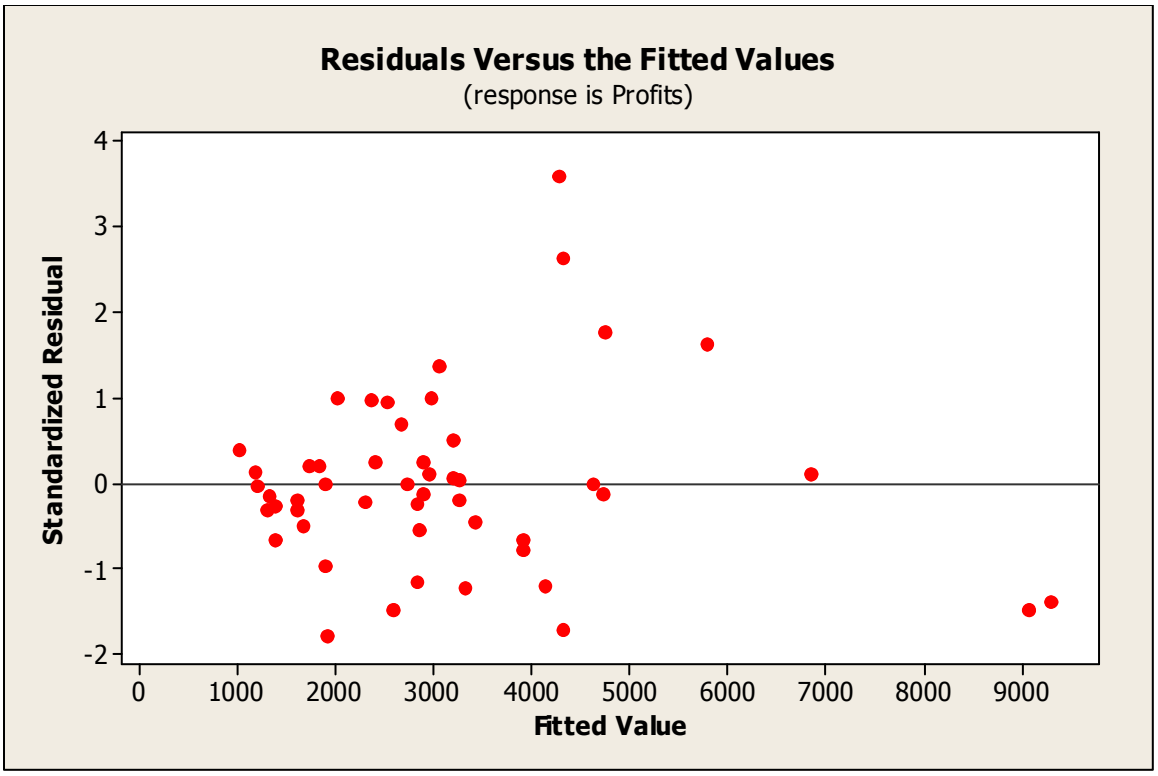




Appendix C.

Model 1.

```
The regression equation is
Profits = 208 + 0.0340 Revenues - 0.00048 Assets + 0.0448 Equity
             + 0.0208 MktVal - 0.00377 Nemployees


Predictor        Coef   SE Coef      T      P
Constant        208.4     273.3   0.76  0.450
Revenues     0.034033  0.006349   5.36  0.000
Assets      -0.000482  0.001033  -0.47  0.643
Equity        0.04483   0.02042   2.20  0.033
MktVal       0.020803  0.002820   ____  _____
Nemployees  -0.003766  0.001326  -2.84  0.007


S = 777.045   R-Sq = 85.1%   R-Sq(adj) = 83.4%


Analysis of Variance

Source          DF         SS        MS      F      P
Regression       5  151381384  30276277  _____  _____
Residual Error  44   26567147    603799
Total           49  177948532


Source      DF    Seq SS
Revenues     1  85086029
Assets       1      3151
Equity       1  31928805
MktVal       1  29496369
Nemployees   1   4867031


Unusual Observations

Obs  Revenues  Profits   Fit  SE Fit  Residual  St Resid
  1     90840     8203  9070     517      -867     -1.49 X
  3    178174     6698  5785     533       913      1.62 X
  4    122379     8460  9286     504      -826     -1.40 X
  9     43957     3833  3068     538       765      1.37 X
 13     56114     6310  4329     186      1981      2.63R
 17    119299     3526  4335     617      -809     -1.71 X
 32     25070     6945  4287     238      2658      3.59R

R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large influence.
```



Model 2.

```
The regression equation is
Profits = 136 + 0.0345 Revenues + 0.0476 Equity + 0.0177 MktVal
          - 0.00347 Nemployees


48 cases used, 2 cases contain missing values


Predictor         Coef     SE Coef      T      P
Constant         136.2       188.7   0.72  0.474
Revenues      0.034493    0.004704   7.33  0.000
Equity         0.04755     0.01479   3.22  0.002
MktVal        0.017686    0.002110   ____  _____
Nemployees  -0.0034739   0.0009736  -3.57  0.001


S = 571.463   R-Sq = 90.8%   R-Sq(adj) = 89.9%


Analysis of Variance

Source           DF         SS        MS       F       P
Regression        4  138087333  34521833  _______  _____
Residual Error   43   14042526    326570
Total            47  152129859

Source       DF    Seq SS
Revenues      1  87141333
Equity        1  26772256
MktVal        1  20015929
Nemployees    1   4157815
```

Unusual Observations

Obs	Revenues	Profits	Fit	SE Fit	Residual	St Resid
1	90840	8203.0	8549.5	366.2	-346.5	-0.79 X
3	178174	6698.0	5961.7	390.6	736.3	1.77 X
4	122379	8460.0	8964.1	355.4	-504.1	-1.13 X
8	78508	6093.0	4589.4	128.9	1503.6	2.70R
9	43957	3833.3	3189.8	379.2	643.5	1.51 X
17	119299	3526.0	4276.6	453.6	-750.6	-2.16RX
43	37073	610.0	2078.2	175.5	-1468.2	-2.70R

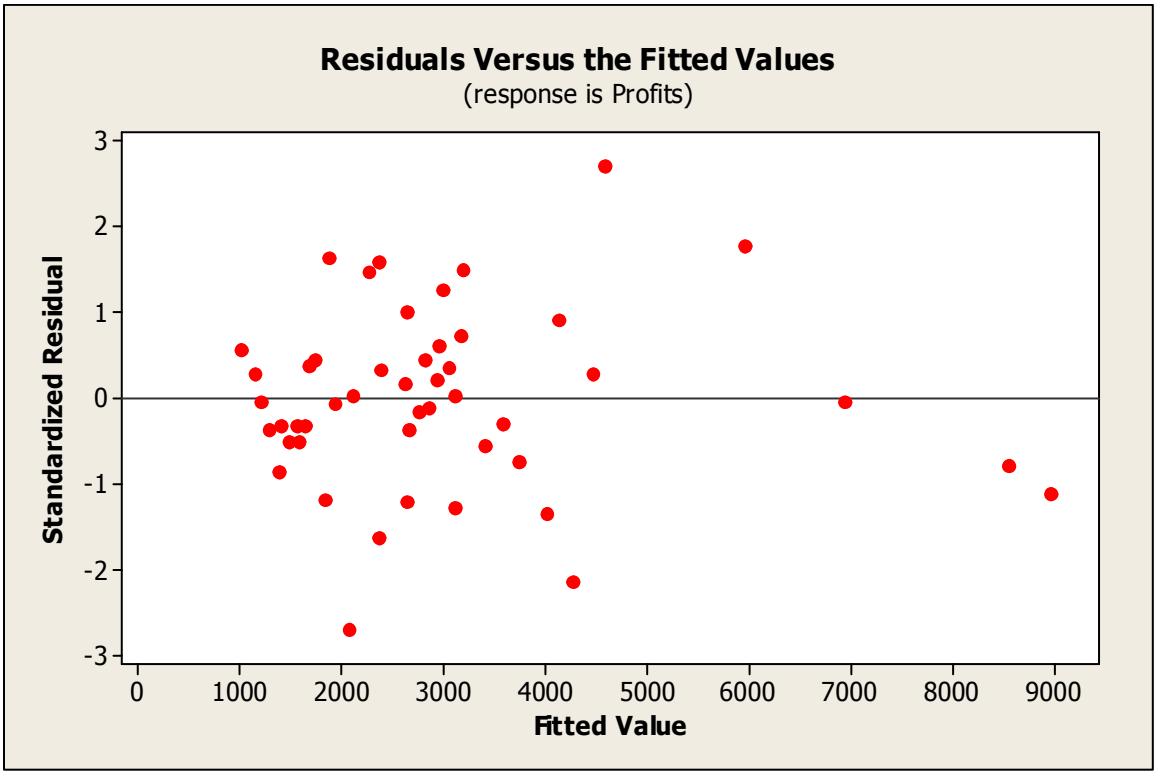
R denotes an observation with a large standardized residual.
X denotes an observation whose X value gives it large influence.

Predicted Values for New Observations

New Obs	Fit	SE Fit	99% CI	99% PI
1	4073.7	136.1	_____	_____

Values of Predictors for New Observations

New Obs	Revenues	Equity	MktVal	Nemployees
1	56114	14920	102932	152000



Number	Profits	Revenues	Assets	Equity	MktVal	Nemployees
1	8203	90840	304012	34438	260147	276000
2	6920	153627	279097	30734	73923	363892
3	6698	178174	228888	17506	54244	608000
4	8460	122379	96064	43660	158784	80000
5	3591	34697	310897	21196	66105	93700
6	3708	30381	365521	21742	58151	69033
7	3104	37609	386555	20893	69420	67250
8	6093	78508	81499	19816	98322	269465
9	3833.27	43957	103626	37635.4	0	72655
10	3332.34	30520	163971	24001.1	87964	40000
11	3055.8	27777	391673	13793	67593	3500
12	4638	53261	58635	22647	105879	128000
13	6310	56114	55947	14920	102932	152000
14	2586	27132	302287	13956	46842	47277
15	1906	31731	292819	8329	29152	56600
16	3210	23585	260159	19837	57840	77000
17	3526	119299	45525	18502	113731	825000
18	2805	61147	60418	11362	28369	121000
19	3077	21734	264562	21337	68437	80360
20	3272	59978	43559	19461	58410	42700
21	3105	24949	80918	15610	40657	51400
22	1226.61	29348	214296	5776.6	0	4824
23	2405	41304	42942	11270	77019	98396
24	2454.9	30194	53964	12789.1	77650	141000
25	3256	36376	35473	17472	54852	39362
26	1203	24374	201907	14007	0	44979
27	3119	42895	31749	16155	65060	121900
28	1991	17760	120003	9574	45270	74000
29	1465	17701	262159	11404	23450	16943
30	2720	32836	32489	16319	41329	43451
31	2664	45187	29600	12766	31577	29313
32	6945	25070	28880	19295	125741	64000
33	3415	35764	27544	12046	113635	106000
34	2793.57	23260	42142	8037.6	54187	114359
35	3261	20561	36301	15165	61132	81000
36	1188	41296	38700	5862	22574	296000
37	1896	14329	157274	12032	35837	43933
38	1086	20038	108199	7932	14738	47700
39	1474	24856	42132	9892	75224	118340
40	4614.1	23637	25812	12613.5	156965	53800
41	1395	14399	194597	7521	33447	3200
42	1966	22473	37776	17285	72754	108000
43	610	37073	259482	19718	0	79000
44	1332	13305	131743	6085	12498	25000
45	901.1	18540	96001	11195.4	12420	40300
46	1305.7	13219	115901	10376	39869	56600
47	1300	28069	28361	5176	22465	173000
48	3303	22629	21453	12359	100631	90500
49	1180	29794	27278	13272	32601	150000
50	2142	29292	20101	6936	63351	136000

Standard Normal Distribution

P(0 ≤ Z ≤ z)

z	0.00	0.01	0.02	0.03	0.04	0.05	0.06	0.07	0.08	0.09
0.0	0.0000	0.0040	0.0080	0.0120	0.0160	0.0199	0.0239	0.0279	0.0319	0.0359
0.1	0.0398	0.0438	0.0478	0.0517	0.0557	0.0596	0.0636	0.0675	0.0714	0.0753
0.2	0.0793	0.0832	0.0871	0.0910	0.0948	0.0987	0.1026	0.1064	0.1103	0.1141
0.3	0.1179	0.1217	0.1255	0.1293	0.1331	0.1368	0.1406	0.1443	0.1480	0.1517
0.4	0.1554	0.1591	0.1628	0.1664	0.1700	0.1736	0.1772	0.1808	0.1844	0.1879
0.5	0.1915	0.1950	0.1985	0.2019	0.2054	0.2088	0.2123	0.2157	0.2190	0.2224
0.6	0.2257	0.2291	0.2324	0.2357	0.2389	0.2422	0.2454	0.2486	0.2517	0.2549
0.7	0.2580	0.2611	0.2642	0.2673	0.2704	0.2734	0.2764	0.2794	0.2823	0.2852
0.8	0.2881	0.2910	0.2939	0.2967	0.2995	0.3023	0.3051	0.3078	0.3106	0.3133
0.9	0.3159	0.3186	0.3212	0.3238	0.3264	0.3289	0.3315	0.3340	0.3365	0.3389
1.0	0.3413	0.3438	0.3461	0.3485	0.3508	0.3531	0.3554	0.3577	0.3599	0.3621
1.1	0.3643	0.3665	0.3686	0.3708	0.3729	0.3749	0.3770	0.3790	0.3810	0.3830
1.2	0.3849	0.3869	0.3888	0.3907	0.3925	0.3944	0.3962	0.3980	0.3997	0.4015
1.3	0.4032	0.4049	0.4066	0.4082	0.4099	0.4115	0.4131	0.4147	0.4162	0.4177
1.4	0.4192	0.4207	0.4222	0.4236	0.4251	0.4265	0.4279	0.4292	0.4306	0.4319
1.5	0.4332	0.4345	0.4357	0.4370	0.4382	0.4394	0.4406	0.4418	0.4429	0.4441
1.6	0.4452	0.4463	0.4474	0.4484	0.4495	0.4505	0.4515	0.4525	0.4535	0.4545
1.7	0.4554	0.4564	0.4573	0.4582	0.4591	0.4599	0.4608	0.4616	0.4625	0.4633
1.8	0.4641	0.4649	0.4656	0.4664	0.4671	0.4678	0.4686	0.4693	0.4699	0.4706
1.9	0.4713	0.4719	0.4726	0.4732	0.4738	0.4744	0.4750	0.4756	0.4761	0.4767
2.0	0.4772	0.4778	0.4783	0.4788	0.4793	0.4798	0.4803	0.4808	0.4812	0.4817
2.1	0.4821	0.4826	0.4830	0.4834	0.4838	0.4842	0.4846	0.4850	0.4854	0.4857
2.2	0.4861	0.4864	0.4868	0.4871	0.4875	0.4878	0.4881	0.4884	0.4887	0.4890
2.3	0.4893	0.4896	0.4898	0.4901	0.4904	0.4906	0.4909	0.4911	0.4913	0.4916
2.4	0.4918	0.4920	0.4922	0.4925	0.4927	0.4929	0.4931	0.4932	0.4934	0.4936
2.5	0.4938	0.4940	0.4941	0.4943	0.4945	0.4946	0.4948	0.4949	0.4951	0.4952
2.6	0.4953	0.4955	0.4956	0.4957	0.4959	0.4960	0.4961	0.4962	0.4963	0.4964
2.7	0.4965	0.4966	0.4967	0.4968	0.4969	0.4970	0.4971	0.4972	0.4973	0.4974
2.8	0.4974	0.4975	0.4976	0.4977	0.4977	0.4978	0.4979	0.4979	0.4980	0.4981
2.9	0.4981	0.4982	0.4982	0.4983	0.4984	0.4984	0.4985	0.4985	0.4986	0.4986
3.0	0.4987	0.4987	0.4987	0.4988	0.4988	0.4989	0.4989	0.4989	0.4990	0.4990
3.1	0.4990	0.4991	0.4991	0.4991	0.4992	0.4992	0.4992	0.4992	0.4993	0.4993
3.2	0.4993	0.4993	0.4994	0.4994	0.4994	0.4994	0.4994	0.4995	0.4995	0.4995
3.3	0.4995	0.4995	0.4995	0.4996	0.4996	0.4996	0.4996	0.4996	0.4996	0.4997
3.4	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4997	0.4998
3.5	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998	0.4998
3.6	0.4998	0.4998	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999
3.7	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999
3.8	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999	0.4999
3.9	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000

Student's t distribution

t_α

$\alpha = P(t \geq t_\alpha)$

ν	0.250	0.200	0.150	**0.100**	0.075	**0.050**	0.030	**0.025**	**0.010**	**0.005**	**0.001**
1	1.00	1.38	1.96	3.08	4.17	6.31	10.58	12.71	31.82	63.66	318.31
2	0.82	1.06	1.39	1.89	2.28	2.92	3.90	4.30	6.96	9.92	22.33
3	0.76	0.98	1.25	1.64	1.92	2.35	2.95	3.18	4.54	5.84	10.21
4	0.74	0.94	1.19	1.53	1.78	2.13	2.60	2.78	3.75	4.60	7.17
5	0.73	0.92	1.16	1.48	1.70	2.02	2.42	2.57	3.36	4.03	5.89
6	0.72	0.91	1.13	1.44	1.65	1.94	2.31	2.45	3.14	3.71	5.21
7	0.71	0.90	1.12	1.41	1.62	1.89	2.24	2.36	3.00	3.50	4.79
8	0.71	0.89	1.11	1.40	1.59	1.86	2.19	2.31	2.90	3.36	4.50
9	0.70	0.88	1.10	1.38	1.57	1.83	2.15	2.26	2.82	3.25	4.30
10	0.70	0.88	1.09	1.37	1.56	1.81	2.12	2.23	2.76	3.17	4.14
11	0.70	0.88	1.09	1.36	1.55	1.80	2.10	2.20	2.72	3.11	4.02
12	0.70	0.87	1.08	1.36	1.54	1.78	2.08	2.18	2.68	3.05	3.93
13	0.69	0.87	1.08	1.35	1.53	1.77	2.06	2.16	2.65	3.01	3.85
14	0.69	0.87	1.08	1.35	1.52	1.76	2.05	2.14	2.62	2.98	3.79
15	0.69	0.87	1.07	1.34	1.52	1.75	2.03	2.13	2.60	2.95	3.73
16	0.69	0.86	1.07	1.34	1.51	1.75	2.02	2.12	2.58	2.92	3.69
17	0.69	0.86	1.07	1.33	1.51	1.74	2.02	2.11	2.57	2.90	3.65
18	0.69	0.86	1.07	1.33	1.50	1.73	2.01	2.10	2.55	2.88	3.61
19	0.69	0.86	1.07	1.33	1.50	1.73	2.00	2.09	2.54	2.86	3.58
20	0.69	0.86	1.06	1.33	1.50	1.72	1.99	2.09	2.53	2.85	3.55
21	0.69	0.86	1.06	1.32	1.49	1.72	1.99	2.08	2.52	2.83	3.53
22	0.69	0.86	1.06	1.32	1.49	1.72	1.98	2.07	2.51	2.82	3.50
23	0.69	0.86	1.06	1.32	1.49	1.71	1.98	2.07	2.50	2.81	3.48
24	0.68	0.86	1.06	1.32	1.49	1.71	1.97	2.06	2.49	2.80	3.47
25	0.68	0.86	1.06	1.32	1.49	1.71	1.97	2.06	2.49	2.79	3.45
26	0.68	0.86	1.06	1.31	1.48	1.71	1.97	2.06	2.48	2.78	3.43
27	0.68	0.86	1.06	1.31	1.48	1.70	1.96	2.05	2.47	2.77	3.42
28	0.68	0.85	1.06	1.31	1.48	1.70	1.96	2.05	2.47	2.76	3.41
29	0.68	0.85	1.06	1.31	1.48	1.70	1.96	2.05	2.46	2.76	3.40
30	0.68	0.85	1.05	1.31	1.48	1.70	1.95	2.04	2.46	2.75	3.39
31	0.68	0.85	1.05	1.31	1.48	1.70	1.95	2.04	2.45	2.74	3.37
32	0.68	0.85	1.05	1.31	1.47	1.69	1.95	2.04	2.45	2.74	3.37
33	0.68	0.85	1.05	1.31	1.47	1.69	1.95	2.03	2.44	2.73	3.36
34	0.68	0.85	1.05	1.31	1.47	1.69	1.95	2.03	2.44	2.73	3.35
35	0.68	0.85	1.05	1.31	1.47	1.69	1.94	2.03	2.44	2.72	3.34
36	0.68	0.85	1.05	1.31	1.47	1.69	1.94	2.03	2.43	2.72	3.33
37	0.68	0.85	1.05	1.30	1.47	1.69	1.94	2.03	2.43	2.72	3.33
38	0.68	0.85	1.05	1.30	1.47	1.69	1.94	2.02	2.43	2.71	3.32
39	0.68	0.85	1.05	1.30	1.47	1.68	1.94	2.02	2.43	2.71	3.31
40	0.68	0.85	1.05	1.30	1.47	1.68	1.94	2.02	2.42	2.70	3.31
50	0.68	0.85	1.05	1.30	1.46	1.68	1.92	2.01	2.40	2.68	3.26
100	0.68	0.85	1.04	1.29	1.45	1.66	1.90	1.98	2.36	2.63	3.17
200	0.68	0.84	1.04	1.29	1.45	1.65	1.89	1.97	2.35	2.60	3.13

Chi-Square Distribution

χ^2_α

$\alpha = P(\chi^2 \geq \chi^2_\alpha)$

ν	0.100	0.050	0.025	0.010	0.005	0.001	0.0001	0.00001	0.000001	0.0000005
1	2.71	3.84	5.02	6.63	7.88	10.83	15.14	19.51	23.93	25.26
2	4.61	5.99	7.38	9.21	10.60	13.82	18.42	23.03	27.63	29.02
3	6.25	7.81	9.35	11.34	12.84	16.27	21.11	25.90	30.66	32.09
4	7.78	9.49	11.14	13.28	14.86	18.47	23.51	28.47	33.38	34.84
5	9.24	11.07	12.83	15.09	16.75	20.52	25.74	30.86	35.89	37.39
6	10.64	12.59	14.45	16.81	18.55	22.46	27.86	33.11	38.26	39.79
7	12.02	14.07	16.01	18.48	20.28	24.32	29.88	35.26	40.52	42.09
8	13.36	15.51	17.53	20.09	21.95	26.12	31.83	37.33	42.70	44.30
9	14.68	16.92	19.02	21.67	23.59	27.88	33.72	39.34	44.81	46.43
10	15.99	18.31	20.48	23.21	25.19	29.59	35.56	41.30	46.86	48.51
11	17.28	19.68	21.92	24.72	26.76	31.26	37.37	43.21	48.87	50.54
12	18.55	21.03	23.34	26.22	28.30	32.91	39.13	45.08	50.83	52.53
13	19.81	22.36	24.74	27.69	29.82	34.53	40.87	46.91	52.75	54.47
14	21.06	23.68	26.12	29.14	31.32	36.12	42.58	48.72	54.64	56.38
15	22.31	25.00	27.49	30.58	32.80	37.70	44.26	50.49	56.49	58.26
16	23.54	26.30	28.85	32.00	34.27	39.25	45.92	52.24	58.32	60.12
17	24.77	27.59	30.19	33.41	35.72	40.79	47.57	53.97	60.13	61.95
18	25.99	28.87	31.53	34.81	37.16	42.31	49.19	55.68	61.91	63.75
19	27.20	30.14	32.85	36.19	38.58	43.82	50.80	57.37	63.68	65.53
20	28.41	31.41	34.17	37.57	40.00	45.31	52.39	59.04	65.42	67.30
21	29.62	32.67	35.48	38.93	41.40	46.80	53.96	60.70	67.15	69.04
22	30.81	33.92	36.78	40.29	42.80	48.27	55.52	62.34	68.86	70.77
23	32.01	35.17	38.08	41.64	44.18	49.73	57.07	63.97	70.55	72.48
24	33.20	36.42	39.36	42.98	45.56	51.18	58.61	65.58	72.23	74.18
25	34.38	37.65	40.65	44.31	46.93	52.62	60.14	67.18	73.89	75.86
26	35.56	38.89	41.92	45.64	48.29	54.05	61.66	68.77	75.55	77.54
27	36.74	40.11	43.19	46.96	49.64	55.48	63.16	70.35	77.19	79.19
28	37.92	41.34	44.46	48.28	50.99	56.89	64.66	71.92	78.82	80.84
29	39.09	42.56	45.72	49.59	52.34	58.30	66.15	73.47	80.44	82.48
30	40.26	43.77	46.98	50.89	53.67	59.70	67.63	75.02	82.04	84.10
35	46.06	49.80	53.20	57.34	60.27	66.62	74.93	82.64	89.95	92.08
40	51.81	55.76	59.34	63.69	66.77	73.40	82.06	90.08	97.65	99.86
50	63.17	67.50	71.42	76.15	79.49	86.66	95.97	104.54	112.61	114.96
100	118.50	124.34	129.56	135.81	140.17	149.45	161.32	172.10	182.13	185.03
150	172.58	179.58	185.80	193.21	198.36	209.26	223.11	235.60	247.15	250.48
200	226.02	233.99	241.06	249.45	255.26	267.54	283.06	297.00	309.84	313.53
224	251.52	259.91	267.35	276.16	282.27	295.14	311.39	325.96	339.36	343.22
250	279.05	287.88	295.69	304.94	311.35	324.83	341.83	357.04	371.02	375.04
500	540.93	553.13	563.85	576.49	585.21	603.45	626.24	646.48	664.96	670.25

Fisher's F distribution

$F_{.05}$

$P(F \geq F_{.05}) = 0.050$

ν_1

ν_2	1	2	3	4	5	6	7	8	9	10	11	12
1	161.4	199.5	215.7	224.6	230.2	234.0	236.8	238.9	240.5	241.9	243.0	243.9
2	18.51	19.00	19.16	19.25	19.30	19.33	19.35	19.37	19.38	19.40	19.40	19.41
3	10.13	9.55	9.28	9.12	9.01	8.94	8.89	8.85	8.81	8.79	8.76	8.74
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.94	5.91
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.77	4.74	4.70	4.68
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.03	4.00
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.64	3.60	3.57
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.35	3.31	3.28
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.14	3.10	3.07
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.98	2.94	2.91
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.85	2.82	2.79
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.80	2.75	2.72	2.69
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.71	2.67	2.63	2.60
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.65	2.60	2.57	2.53
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.59	2.54	2.51	2.48
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.39	2.35	2.31	2.28
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32	2.28	2.25
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.34	2.30	2.26	2.23
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.32	2.27	2.24	2.20
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.30	2.25	2.22	2.18
25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.28	2.24	2.20	2.16
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.21	2.16	2.13	2.09
31	4.16	3.30	2.91	2.68	2.52	2.41	2.32	2.25	2.20	2.15	2.11	2.08
32	4.15	3.29	2.90	2.67	2.51	2.40	2.31	2.24	2.19	2.14	2.10	2.07
33	4.14	3.28	2.89	2.66	2.50	2.39	2.30	2.23	2.18	2.13	2.09	2.06
34	4.13	3.28	2.88	2.65	2.49	2.38	2.29	2.23	2.17	2.12	2.08	2.05
35	4.12	3.27	2.87	2.64	2.49	2.37	2.29	2.22	2.16	2.11	2.07	2.04
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.08	2.04	2.00
50	4.03	3.18	2.79	2.56	2.40	2.29	2.20	2.13	2.07	2.03	1.99	1.95
100	3.94	3.09	2.70	2.46	2.31	2.19	2.10	2.03	1.97	1.93	1.89	1.85
200	3.89	3.04	2.65	2.42	2.26	2.14	2.06	1.98	1.93	1.88	1.84	1.80

Studentized range values q(.05)

k = number of groups

df	2	3	4	5	6	7	8	9	10
1	17.969	26.976	32.819	37.082	40.408	43.119	45.397	47.357	49.071
2	6.085	8.331	9.798	10.881	11.734	12.435	13.027	13.539	13.988
3	4.501	5.91	6.825	7.502	8.037	8.478	8.852	9.177	9.462
4	3.926	5.04	5.757	6.287	6.706	7.053	7.347	7.602	7.826
5	3.635	4.602	5.218	5.673	6.033	6.33	6.582	6.801	6.995
6	3.46	4.339	4.896	5.305	5.628	5.895	6.122	6.319	6.493
7	3.344	4.165	4.681	5.06	5.359	5.606	5.815	5.997	6.158
8	3.261	4.041	4.529	4.886	5.167	5.399	5.596	5.767	5.918
9	3.199	3.948	4.415	4.755	5.024	5.244	5.432	5.595	5.738
10	3.151	3.877	4.327	4.654	4.912	5.124	5.304	5.46	5.598
11	3.113	3.82	4.256	4.574	4.823	5.028	5.202	5.353	5.486
12	3.081	3.773	4.199	4.508	4.75	4.95	5.119	5.265	5.395
13	3.055	3.734	4.151	4.453	4.69	4.884	5.049	5.192	5.318
14	3.033	3.701	4.111	4.407	4.639	4.829	4.99	5.13	5.253
15	3.014	3.673	4.076	4.367	4.595	4.782	4.94	5.077	5.198
16	2.998	3.649	4.046	4.333	4.557	4.741	4.896	5.031	5.15
17	2.984	3.628	4.02	4.303	4.524	4.705	4.858	4.991	5.108
18	2.971	3.609	3.997	4.276	4.494	4.673	4.824	4.955	5.071
19	2.96	3.593	3.977	4.253	4.468	4.645	4.794	4.924	5.037
20	2.95	3.578	3.958	4.232	4.445	4.62	4.768	4.895	5.008
21	2.941	3.565	3.942	4.213	4.424	4.597	4.743	4.87	4.981
22	2.933	3.553	3.927	4.196	4.405	4.577	4.722	4.847	4.957
23	2.926	3.542	3.914	4.18	4.388	4.558	4.702	4.826	4.935
24	2.919	3.532	3.901	4.166	4.373	4.541	4.684	4.807	4.915
25	2.913	3.523	3.89	4.153	4.358	4.526	4.667	4.789	4.897
26	2.907	3.514	3.88	4.141	4.345	4.511	4.652	4.773	4.88
27	2.902	3.506	3.87	4.13	4.333	4.498	4.638	4.758	4.864
28	2.897	3.499	3.861	4.12	4.322	4.486	4.625	4.745	4.85
29	2.892	3.493	3.853	4.111	4.311	4.475	4.613	4.732	4.837
30	2.888	3.486	3.845	4.102	4.301	4.464	4.601	4.72	4.824