#### IENAC22 / Econometrics 1 / Applied Problem Set 2

#### Topic: Further multivariate regression

- This problem set is an introduction to the **programming features** of EViews 6 (or it can be completed using menu commands in EViews 12). The data is available on the website as metals\_data.txt.
- The problem set covers (i) file import, (ii) workfile and series creation, (iii) graphical analysis, (iv) ordinary least squares, (v) testing of linear hypotheses, (vi) matrix manipulation, and (vii) storing and execution of EViews 6 program (.prg) files.
- We use production data for the U.S. metals industry. There are 27 statewide observations on (i) value added (output  $Q_i$ ), (ii) labour input  $(L_i)$ , and (iii) gross value of plant and equipment (capital stock  $K_i$ ). The columns are ordered as (i), (ii), (iii).
- We specify a Cobb-Douglas production function Q = Q(L, K):

$$Q_i = \alpha_0^{\star} L_i^{\alpha_1} K_i^{\alpha_2}, \quad i = 1, 2, \dots, n,$$

from which:

$$\ln(Q_i) = \alpha_0 + \alpha_1 \ln(L_i) + \alpha_2 \ln(K_i) + u_i$$

is an econometric model.

- Follow the steps described in Figures 1–13, and respond to the following questions:
  - 1. Regress log output on a constant, log labour input, and log capital input (eq01):



with standard errors [ ], [ ], and [ ] respectively. Check using t statistics whether the estimated coefficients are *individually* significant at the 99% level.

Test whether the labour elasticity of output (∂ ln(Q<sub>i</sub>)/∂ ln(L<sub>i</sub>)) is equal to
 1, at the 95% level:



with t statistic (first, give the t statistic in terms of  $\hat{\alpha}_j$ ; then substitute in the estimated value; finally, simplify):



Use the full available accuracy of the estimated coefficients when computing the results. Since (give the absolute computed value of t from above; compare this to the appropriate critical value  $t_{crit}(n-k)$ ):



we reject / do not reject the null hypothesis at the 95% level. Perform the same test using the F statistic (use  $F(1, n-k) = t^2(n-k)$  to compute the F statistic; then compare this to the appropriate critical value  $F_{crit}(1, n-k)$ ):



and so we reject / do not reject the null at the 95% level.

3. Test for **constant returns to scale** at the 95% level of significance (also, how would you define increasing and decreasing returns to scale?). Note that:

$$Q(\lambda L_i, \lambda K_i) = \alpha_0 (\lambda L_i)^{\alpha_1} (\lambda K_i)^{\alpha_2}$$
$$= \alpha_0 \lambda^{\alpha_1} L_i^{\alpha_1} \lambda^{\alpha_2} K_i^{\alpha_2}$$
$$= \lambda^{(\alpha_1 + \alpha_2)} Q_i = \lambda Q_i$$

if and only if  $\alpha_1 + \alpha_2 = 1$ . So, the hypothesis test of interest is:



from which we can construct the F statistic (first, write this in terms of  $\widehat{\alpha}_j$ ; and identify the distribution F(q, n - k) that the F statistic follows):



We then need to compute both  $\widehat{\sigma}^2$  and  $\widehat{\operatorname{Var}}(\cdot)$ , where

$$\widehat{\sigma}^2 = \frac{\widehat{u}'\widehat{u}}{n-k} \approx \boxed{[\qquad]}$$

Then,  $\widehat{\operatorname{Var}}(\widehat{\alpha}) = \widehat{\sigma}^2 (X'X)^{-1}$ , where  $(X'X)^{-1} \approx$ :



Note that  $\widehat{\operatorname{Var}}(\widehat{\alpha}_1 + \widehat{\alpha}_2) = \widehat{\operatorname{Var}}(\widehat{\alpha}_1) + \widehat{\operatorname{Var}}(\widehat{\alpha}_2) + 2\widehat{\operatorname{Cov}}(\widehat{\alpha}_1, \widehat{\alpha}_2)$ . Then (substitute in the computed values, and simplify):



So (compute the F statistic, and compare it to the appropriate critical value):

$$F \approx \boxed{[]} > / < F_{\boxed{[]}}(\boxed{[]}, \boxed{[]}) \approx \boxed{[]}$$

and so we reject / do not reject the null at the 95% level.

4. A generalization of the Cobb-Douglas model is the **translog model** (eq02):

$$\ln(Q_i) = \alpha_0 + \alpha_1 \ln(L_i) + \alpha_2 \ln(K_i) + \frac{1}{2} \alpha_3 (\ln(L_i))^2 + \frac{1}{2} \alpha_4 (\ln(K_i))^2 + \alpha_5 \ln(L_i) \ln(K_i) + u_i,$$

which reduces to the Cobb-Douglas model under  $H_0$ :  $\alpha_3 = \alpha_4 = \alpha_5 = 0$ . Run the translog regression:

$$\widehat{\ln(Q_i)} = [ ] + [ ] \ln(L_i) + [ ] \ln(K_i)$$
  
+ [ ]  $(\ln(L_i))^2 + [ ] (\ln(K_i))^2 + [ ] \ln(L_i) \ln(K_i)$ 

EViews gives the "Wald" F statistic as:



and so we reject / do not reject the null hypothesis at the 95% level.

5. What is the estimated **capital elasticity of output** from the *translog* model?



increase/decrease in output.

### Importing Data into a Workfile

### and Descriptive Statistics

# RECORD THE COMMAND LINES IN A TEXT FILE AS YOU GO!



Figure 1: Use programming commands rather than menu-driven commands throughout this Problem Set, if possible. See the top of each screen! Create a workfile and import the datafile metals\_data.txt into objects obs, q, l and k (output, labour and capital). You will need to specify the path appropriately.

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Figure 2: Create the log-transformed series  $\log q = \log(q)$  and  $\log k = \log(k)$ .

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Figure 3: Create a series  $\log l = \log(l)$ , and create a scatterplot of logq against logk, and name the graph 'scatter1'.



Figure 4: Display the scatterplot 'scatter1', and create a scatterplot of logq against logl, and name this graph 'scatter2'.



Figure 5: Display the scatterplot 'scatter2'. Create an equation *object* eq01. Note that the model has not yet been specified.

# A First Regression

## and Hypothesis Testing

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Figure 6: For eq01, run the Cobb-Douglas regression of logq on a constant, logl and logk, using ordinary least squares. Perform the hypothesis test (Wald) of  $H_0$ :  $\alpha_1 = 1$  against  $H_1$ :  $\alpha_1 \neq 1$ .

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Figure 7: For eq01, perform the test (Wald) of  $H_0: \alpha_1 + \alpha_2 = 1$  against  $H_1: \alpha_1 + \alpha_2 \neq 1$ . Create a series 'uhat' equal to the current estimated residual vector 'resid'.

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Figure 8: Create a  $27 \times 1$  vector of ones, 'cons'. Create a group, named 'gp1', containing cons, logl and logk. Create a matrix object, named x, containing group gp1.

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Figure 9: Compute  $(X'X)^{-1}$  directly from X. Compute  $\widehat{\sigma}^2 = \widehat{u}'\widehat{u}/(n-k)$  directly from uhat. This can be used directly to give  $\widehat{\operatorname{Var}}(\widehat{\alpha}) = \widehat{\sigma}^2 (X'X)^{-1}$ .

# A Second Regression

## and Hypothesis Testing

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Figure 10: Create an equation object eq02, and run the translog regression of logq on a constant, logl, logk, logl squared, logk squared, and logl×logk, using ordinary least squares. Perform the test (Wald) of  $H_0: \alpha_3 = \alpha_4 = \alpha_5 = 0$  against  $H_1:$  not  $H_0$ .

## Saving the Workfile

## and Running a Simple Program



Figure 11: Save the workfile as 'metals\_workfile.wf1', with an appropriate path. Copy all of the above EViews commands into a text file metals\_prog.prg

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EViews      File Edit Object Vew Proc Quck o     open "C1Documents and Settingslaw/      Workfile: METALS_WORKFIL      Workfile: NETALS_WORKFIL      Workfile: 17 - 27 obs     Sample: 127 - 27	Continue Window Help Constitution and support Constitution C	org" Sample Jay Filter.* DGC (c:\\documents at Gcov/Paste (hergeText) id Settings\\awforstBure	nd settings\lawfors Find]Replace] [Encrypt au/data/metals_data	t\bureau\data 🖕 🗍	
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EViews      File Edit Object Vew Proc Quck o     open "C1Documents and Settings!law/      Workfrile: MFTALS_WORKFIL      Workfrile: MFTALS_WORKFIL      Workfrile: 17 - 27 obs     Sample: 127	Cotions Window Help pretBureau/data/metals_prog.p (- (c:\documents and s Disp	ng" Sanple Sanple Jac Filter: Cooy Paste [tergeText] Cooy Paste [tergeText] d SettingsUawforst/Bure d SettingsUawforst/Bure d	id settings\lawfors Find Replace) [Encrypt auddalarmetals_data.	t\bureau\data [= ] [] ] bd" obs q i k	
Views      File Edit Object Vew Proc Quck o     open "C1Documents and Settings!law/      workfrile: MFTAL S_WORK/Fil      Workfrile: MFTAL S_WORK/Fil      Proc Object   Print   Save Details     Sample: 127 - 27 obs     Sample: 127 - 27 obs	Cotions Window Help pretBure au/data/metals_prog.p (- (c:\documents and s Display au/data/metals_prog.p Display au/data/metals_prog.p Display au/data/metals_prog.p (Ran [Print]Save[SaveAo Qui Writerate metals u1 127 read(t=b)*(2*Documents ar series log4=log(0) series log4=	ng" Serr Sample Jais Filter: Cooy Peste [MergeText] Cooy Peste [MergeText] d SettingsVawforsfiBure d spose00"h0 "uhat/24 *2) (logk*2) (logt*logk)	nd settings\lawfors Find Replace) [Encryp auddatametals_data	t\bureau\data (= ) ( ) bd" obs q i k	
EViews      File Edit Object Vew Proc Quck o     open "C1Documents and Settings!law/      workfrile: MFTAL S_WORK/Fil      Workfrile: MFTAL S_WORK/Fil      Proc Object   Print   Save Details     Sample: 127 - 27 obs     Sample: 127 - 27 obs	Cotions Window Help pretBure au/data/metals_prog.p (c:\documents and s Display au/data/metals_prog.p Display au/data/metals_prog.p Display au/data/metals_prog.p (Ran [Print]Save[SaveAo Qu Writerate metals u1 27 read(t-b)*(2*Documents ar series log4=log(0) series log4=log(0	ng" Serr Sample Jais Filter: Cooy Peste [tergeText] Cooy Peste [tergeText] d SettingsVawforstBure 1 Spose(0)"h) "Uhat/24 *2) (logk*2) (logI*logk) d SettingsVawforstBure	nd settings\lawfors Find Replace) [Encryp auddata/metals_data.	t\bureau\data [] [] ] td" obs q I k	

Figure 12: EViews 6 code metals\_prog.prg, opened in Notepad. Code can be opened in EViews 6, with the 'open' command. Note that four additional lines of code have been added here (lines 21, 22, 27 and 28) / you should add these too.



Figure 13: Close the open workfile (there is no need to save this). The code can then be run within EViews 6 using the 'run' command, or by clicking on the 'Run' button. This procedure is very useful in practice since it enables a (long) sequence of commands to be executed repeatedly, e.g. with modified data, or with modified models.

Areas Under the Normal Curve

Ζ	Cum p	Tail p	Z	Cum p	Tail p									
0.00	0.5000	0.5000	0.40	0.6554	0.3446	0.80	0.7881	0.2119	1.20	0.8849	0.1151	1.60	0.9452	0.0548
0.01	0.5040	0.4960	0.41	0.6591	0.3409	0.81	0.7910	0.2090	1.21	0,8869	0.1131	1.61	0.9463	0.0537
0.02	0.5080	0.4920	0.42	0.6628	0.3372	0.82	0.7939	0.2061	1.22	0.8888	0.1112	1.62	0.9474	0.0526
0.03	0.5120	0.4880	0.43	0.6664	0.3336	0.83	0.7967	0.2033	1.23	0.8907	0.1093	1.63	0.9484	0.0516
0.04	0.5160	0.4840	0.44	0.6700	0.3300	0.84	0.7995	0.2005	1.24	0.8925	0.1075	1.64	0.9495	0.0505
0.05	0.5199	0.4801	0.45	0.6736	0.3264	0.85	0.8023	0.1977	1.25	0.8944	0.1056	1.65	0.9505	0.0495
0.06	0.5239	0.4761	0.46	0.6772	0.3228	0.86	0.8051	0.1949	1.26	0.8962	0.1038	1.66	0.9515	0.0485
0.07	0.5279	0.4721	0.47	0.6808	0.3192	0.87	0.8078	0.1922	1.27	0.8980	0.1020	1.67	0.9525	0.0475
0.08	0.5319	0.4681	0.48	0.6844	0.3156	0.88	0.8106	0.1894	1.28	0.8997	0,1003	1.68	0.9535	0.0465
0.09	0.5359	0.4641	0.49	0.6879	0.3121	0.89	0.8133	0.1867	1.29	0.9015	0.0985	1.69	0.9545	0.0455
0.10	0.5398	0.4602	0.50	0.6915	0.3085	0.90	0.8159	0.1841	1.30	0.9032	0.0968	1.70	0.9554	0.0446
0.11	0.5438	0.4562	0.51	0.6950	0.3050	0.91	0.8186	0.1814	1.31	0.9049	0.0951	1.71	0.9564	0.0436
0.12	0.5478	0.4522	0.52	0.6985	0.3015	0.92	0.8212	0.1788	1.32	0.9066	0.0934	1.72	0.9573	0.0427
0.13	0.5517	0.4483	0.53	0.7019	0.2981	0.93	0.8238	0.1762	1.33	0.9082	0.0918	1.73	0.9582	0.0418
0.14	0,5557	0.4443	0.54	0,7054	0.2946	0.94	0.8264	0.1736	1.34	0.9099	0.0901	1.74	0,9591	0.0409
0.15	0.5596	0.4404	0.55	0.7088	0.2912	0.95	0.8289	0.1711	1.35	0.9115	0.0885	1.75	0.9599	0.0401
0.16	0.5636	0.4364	0.56	0.7123	0.2877	0.96	0.8315	0.1685	1.36	0.9131	0.0869	1.76	0.9608	0.0392
0.17	0.5675	0.4325	0.57	0.7157	0.2843	0.97	0.8340	0.1660	1.37	0.9147	0.0853	1.77	0.9616	0.0384
0.18	0.5714	0.4286	0.58	0.7190	0.2810	0.98	0.8365	0.1635	1.38	0.9162	0.0838	1.78	0.9625	0.0375
0.19	0.5753	0.4247	0.59	0.7224	0.2776	0.99	0.8389	0.1611	1.39	0.9177	0.0823	1.79	0.9633	0.0367
0.20	0.5793	0.4207	0.60	0.7257	0.2743	1.00	0.8413	0.1587	1.40	0.9192	0,0808	1.80	0.9641	0.0359
0.21	0.5832	0.4168	0.61	0.7291	0.2709	1.01	0.8438	0.1562	1.41	0.9207	0.0793	1.81	0.9649	0.0351
0.22	0.5871	0.4129	0.62	0.7324	0.2676	1.02	0.8461	0.1539	1.42	0.9222	0.0778	1.82	0.9656	0.0344
0.23	0.5910	0.4090	0.63	0.7357	0.2643	1.03	0.8485	0.1515	1.43	0.9236	0.0764	1.83	0.9664	0.0336
0.24	0.5948	0.4052	0.64	0.7389	0.2611	1.04	0.8508	0.1492	1.44	0.9251	0.0749	1.84	0.9671	0.0329
0.25	0.5987	0.4013	0.65	0.7422	0.2578	1.05	0.8531	0.1469	1.45	0.9265	0.0735	1.85	0.9678	0.0322
0.26	0.6026	0.3974	0.66	0.7454	0.2546	1.06	0.8554	0.1446	1.46	0.9279	0.0721	1.86	0,9686	0.0314
0.27	0,6064	0.3936	0.67	0.7486	0.2514	1.07	0.8577	0.1423	1.47	0.9292	0,0708	1.87	0.9693	0.0307
0.28	0.6103	0.3897	0.68	0.7517	0,2483	1.08	0.8599	0.1401	1.48	0,9306	0,0694	1.88	0,9699	0.0301
0.29	0.6141	0.3859	0.69	0.7549	0.2451	1.09	0.8621	0.1379	1.49	0.9319	0,0681	1.89	0,9706	0.0294
0.30	0.6179	0.3821	0.70	0,7580	0.2420	1.10	0.8643	0.1357	1.50	0,9332	0,0668	1.90	0.9713	0.0287
0.31	0.6217	0.3783	0.71	0.7611	0.2389	1.11	0.8665	0.1335	1.51	0.9345	0,0655	1.91	0.9719	0.0281
0.32	0.6255	0.3745	0.72	0.7642	0.2358	1.12	0.8686	0.1314	1.52	0,9357	0.0643	1.92	0.9726	0.0274
0.33	0.6293	0.3707	0.73	0.7673	0.2327	1.13	0.8708	0.1292	1.53	0,9370	0,0630	1.93	0.9732	0.0268
0.34	0.6331	0.3669	0.74	0.7704	0.2296	1.14	0.8729	0.1271	1.54	0.9382	0,0618	1.94	0.9738	0.0262
0.35	0.6368	0.3632	0.75	0.7734	0.2266	1.15	0.8749	0.1251	1.55	0.9394	0,0606	1.95	0.9744	0.0256
0.36	0,6406	0.3594	0.76	0.7764	0.2236	1.16	0,8770	0,1230	1.56	0,9406	0,0594	1,96	0,9750	0.0250
0.37	0.6443	0.3557	0.77	0.7794	0.2206	1.17	0,8790	0,1210	1.57	0.9418	0,0582	1,97	0,9756	0.0244
0.38	0.6480	0.3520	0.78	0.7823	0.2177	1.18	0,8810	0,1190	1.58	0.9429	0.0571	1,98	0.9761	0.0239
0.39	0,6517	0.3483	0.79	0,7852	0.2148	1.19	0,8830	0,1170	1.59	0.9441	0,0559	1,99	0,9767	0.0233

Figure 14: Statistical table for N(0, 1).

	2-	tailed testir	ıg	1-tailed testing			
df		••					
	0.1	0.05	0.01	0.1	0.05	0.01	
5	2.015	2.571	4.032	1.476	2.015	3.365	
6	1.943	2.447	3.707	1.440	1.943	3.143	
7	1.895	2.365	3.499	1.415	1.895	2.998	
8	1.860	2.306	3.355	1.397	1.860	2.896	
9	1.833	2.262	3.250	1.383	1.833	2.821	
10	1.812	2.228	3.169	1.372	1.812	2.764	
11	1.796	2.201	3.106	1.363	1.796	2.718	
12	1.782	2.179	3.055	1.356	1.782	2.681	
13	1.771	2.160	3.012	1.350	1.771	2.650	
14	1.761	2.145	2.977	1.345	1.761	2.624	
15	1.753	2.131	2.947	1.341	1.753	2.602	
16	1.746	2.120	2.921	1.337	1.746	2.583	
17	1.740	2.110	2.898	1.333	1.740	2.567	
18	1.734	2.101	2.878	1.330	1.734	2.552	
19	1.729	2.093	2.861	1.328	1.729	2.539	
20	1.725	2.086	2.845	1.325	1.725	2.528	
21	1.721	2.080	2.831	1.323	1.721	2.518	
22	1.717	2.074	2.819	1.321	1.717	2.508	
23	1.714	2.069	2.807	1.319	1.714	2.500	
24	1.711	2.064	2.797	1.318	1.711	2.492	
25	1.708	2.060	2.787	1.316	1.708	2.485	
26	1.706	2.056	2.779	1.315	1.706	2.479	
27	1.703	2.052	2.771	1.314	1.703	2.473	
28	1.701	2.048	2.763	1.313	1.701	2.467	
29	1.699	2.045	2.756	1.311	1.699	2.462	
30	1.697	2.042	2.750	1.310	1.697	2.457	
40	1.684	2.021	2.704	1.303	1.684	2.423	
50	1.676	2.009	2.678	1.299	1.676	2.403	
60	1.671	2.000	2.660	1.296	1.671	2.390	
80	1.664	1.990	2.639	1.292	1.664	2.374	
100	1.660	1.984	2.626	1.290	1.660	2.364	
120	1.658	1.980	2.617	1.289	1.658	2.358	
••	1.645	1.960	2.576	1.282	1.645	2.327	

#### Critical Values of the <u>t</u> Distribution

Figure 15: Statistical table for Student's t(r)

#### Critical Values of the <u>F</u> Distribution ( $\alpha = .05$ )

df	df between										
within	1	2	3	4	5	6	7	8	12	24	8
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.68	4.53	4.37
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.00	3.84	3.67
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.57	3.41	3.23
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.28	3.12	2.93
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.07	2.90	2.71
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	2.91	2.74	2.54
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.79	2.61	2.41
12	4.75	3.89	3.49	3.26	3.11	3.00	2.91	2.85	2.69	2.51	2.30
13	4.67	3.81	3.41	3.18	3.03	2.92	2.83	2.77	2.60	2.42	2.21
14	4.60	3.74	3.34	3.11	2.96	2.85	2.76	2.70	2.53	2.35	2.13
15	4.54	3.68	3.29	3.06	2.90	2.79	2.71	2.64	2.48	2.29	2.07
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.42	2.24	2.01
17	4.45	3.59	3.20	2.96	2.81	2.70	2.61	2.55	2.38	2.19	1.96
18	4.41	3.55	3.16	2.93	2.77	2.66	2.58	2.51	2.34	2.15	1.92
19	4.38	3.52	3.13	2.90	2.74	2.63	2.54	2.48	2.31	2.11	1.88
20	4.35	3.49	3.10	2.87	2.71	2.60	2.51	2.45	2.28	2.08	1.84
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.25	2.05	1.81
22	4.30	3.44	3.05	2.82	2.66	2.55	2.46	2.40	2.23	2.03	1.78
23	4.28	3.42	3.03	2.80	2.64	2.53	2.44	2.37	2.20	2.01	1.76
24	4.26	3.40	3.01	2.78	2.62	2.51	2.42	2.36	2.18	1.98	1.73
25	4.24	3.39	2.99	2.76	2.60	2.49	2.40	2.34	2.16	1.96	1.71
26	4.23	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.15	1.95	1.69
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.31	2.13	1.93	1.67
28	4.20	3.34	2.95	2.71	2.56	2.45	2.36	2.29	2.12	1.91	1.66
29	4.18	3.33	2.93	2.70	2.55	2.43	2.35	2.28	2.10	1.90	1.64
30	4.17	3.32	2.92	2.69	2.53	2.42	2.33	2.27	2.09	1.89	1.62
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.00	1.79	1.51
60	4.00	3.15	2.76	2.53	2.37	2.25	2.17	2.10	1.92	1.70	1.39
80	3.96	3.11	2.72	2.49	2.33	2.21	2.13	2.06	1.88	1.65	1.33
100	3.94	3.09	2.70	2.46	2.31	2.19	2.10	2.03	1.85	1.63	1.28
120	3.92	3.07	2.68	2.45	2.29	2.18	2.09	2.02	1.83	1.61	1.26
00	3.84	3.00	2.61	2.37	2.22	2.10	2.01	1.94	1.75	1.52	1.00

Figure 16: Statistical table for F(m,n) at the 5% level

#### Critical Values of the <u>F</u> Distribution ( $\alpha = .01$ )

df	df between										
within	1	2	3	4	5	6	7	8	12	24	8
5	16.26	13.27	12.06	11.39	10.97	10.67	10.46	10.29	9.89	9.47	9.02
6	13.75	10.92	9.78	9.15	8.75	8.47	8.26	8.10	7.72	7.31	6.88
7	12.25	9.55	8.45	7.85	7.46	7.19	6.99	6.84	6.47	6.07	5.65
8	11.26	8.65	7.59	7.01	6.63	6.37	6.18	6.03	5.67	5.28	4.86
9	10.56	8.02	6.99	6.42	6.06	5.80	5.61	5.47	5.11	4.73	4.31
10	10.04	7.56	6.55	5.99	5.64	5.39	5.20	5.06	4.71	4.33	3.91
11	9.65	7.21	6.22	5.67	5.32	5.07	4.89	4.74	4.40	4.02	3.60
12	9.33	6.93	5.95	5.41	5.06	4.82	4.64	4.50	4.16	3.78	3.36
13	9.07	6.70	5.74	5.21	4.86	4.62	4.44	4.30	3.96	3.59	3.17
14	8.86	6.51	5.56	5.04	4.69	4.46	4.28	4.14	3.80	3.43	3.01
15	8.68	6.36	5.42	4.89	4.56	4.32	4.14	4.00	3.67	3.29	2.87
16	8.53	6.23	5.29	4.77	4.44	4.20	4.03	3.89	3.55	3.18	2.75
17	8.40	6.11	5.18	4.67	4.34	4.10	3.93	3.79	3.46	3.08	2.65
18	8.29	6.01	5.09	4.58	4.25	4.01	3.84	3.71	3.37	3.00	2.57
19	8.18	5.93	5.01	4.50	4.17	3.94	3.77	3.63	3.30	2.92	2.49
20	8.10	5.85	4.94	4.43	4.10	3.87	3.70	3.56	3.23	2.86	2.42
21	8.02	5.78	4.87	4.37	4.04	3.81	3.64	3.51	3.17	2.80	2.36
22	7.95	5.72	4.82	4.31	3.99	3.76	3.59	3.45	3.12	2.75	2.31
23	7.88	5.66	4.76	4.26	3.94	3.71	3.54	3.41	3.07	2.70	2.26
24	7.82	5.61	4.72	4.22	3.90	3.67	3.50	3.36	3.03	2.66	2.21
25	7.77	5.57	4.68	4.18	3.85	3.63	3.46	3.32	2.99	2.62	2.17
26	7.72	5.53	4.64	4.14	3.82	3.59	3.42	3.29	2.96	2.58	2.13
27	7.68	5.49	4.60	4.11	3.78	3.56	3.39	3.26	2.93	2.55	2.10
28	7.64	5.45	4.57	4.07	3.75	3.53	3.36	3.23	2.90	2.52	2.07
29	7.60	5.42	4.54	4.04	3.73	3.50	3.33	3.20	2.87	2.49	2.04
30	7.56	5.39	4.51	4.02	3.70	3.47	3.30	3.17	2.84	2.47	2.01
40	7.31	5.18	4.31	3.83	3.51	3.29	3.12	2.99	2.66	2.29	1.81
60	7.08	4.98	4.13	3.65	3.34	3.12	2.95	2.82	2.50	2.12	1.60
80	6.96	4.88	4.04	3.56	3.26	3.04	2.87	2.74	2.42	2.03	1.50
100	6.90	4.82	3.98	3.51	3.21	2.99	2.82	2.69	2.37	1.98	1.43
120	6.85	4.79	3.95	3.48	3.17	2.96	2.79	2.66	2.34	1.95	1.38
00	6.64	4.61	3.78	3.32	3.02	2.80	2.64	2.51	2.19	1.79	1.00

Figure 17: Statistical table for F(m,n) at the 1% level

	Arres in the Harry Tail					
df	Area in the Opper Tail					
	0.99	0.95	0.9	0.1	0.05	0.01
1	0.000	0.004	0.016	2.706	3.841	6.635
2	0.020	0.103	0.211	4.605	5.991	9.210
3	0.115	0.352	0.584	6.251	7.815	11.345
4	0.297	0.711	1.064	7.779	9.488	13.277
5	0.554	1.145	1.610	9.236	11.070	15.086
6	0.872	1.635	2.204	10.645	12.592	16.812
7	1.239	2.167	2.833	12.017	14.067	18.475
8	1.646	2.733	3.490	13.362	15.507	20.090
9	2.088	3.325	4.168	14.684	16.919	21.666
10	2.558	3.940	4.865	15.987	18.307	23.209
11	3.053	4.575	5.578	17.275	19.675	24.725
12	3.571	5.226	6.304	18.549	21.026	26.217
13	4.107	5.892	7.042	19.812	22.362	27.688
14	4.660	6.571	7.790	21.064	23.685	29.141
15	5.229	7.261	8.547	22.307	24.996	30.578
16	5.812	7.962	9.312	23.542	26.296	32.000
17	6.408	8.672	10.085	24.769	27.587	33.409
18	7.015	9.390	10.865	25.989	28.869	34.805
19	7.633	10.117	11.651	27.204	30.144	36.191
20	8.260	10.851	12.443	28.412	31.410	37.566
21	8.897	11.591	13.240	29.615	32.671	38.932
22	9.542	12.338	14.041	30.813	33.924	40.289
23	10.196	13.091	14.848	32.007	35.172	41.638
24	10.856	13.848	15.659	33.196	36.415	42.980
25	11.524	14.611	16.473	34.382	37.652	44.314

#### Critical Values of the $\chi^2$ Distribution

Figure 18: Statistical table for  $\chi^2(q)$