January Examination Period 2025

ECN224 Econometrics 1 Duration: 2 hours

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Answer ALL questions. The appendix contains tables with the critical values of the standard normal distribution and the F distribution. Ensure that your working is clearly shown with all steps of your calculation included in your answer document, including any formula used.

Non-programmable calculators are permitted in this examination. Please state on your answer book the name and type of machine used.

Complete all rough workings in the answer book and cross through any work that is not to be assessed.

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EXAM PAPERS MUST NOT BE REMOVED FROM THE EXAM ROOM

Examiner: Dr. Štěpána Lazarová

The questions 1 and 2 below are based on a dataset containing data on earnings, height, and other characteristics of a random sample of 17,870 U.S. workers. In particular, we will use the following variables:

- *earnings*: annual labor earnings expressed in $2012,
- *height*: height without shoes in inches,
- *sex*: 1 if worker is male, 0 if female,
- *educ*: years of education.

In addition, using variable *educ*, the following exhaustive and mutually exclusive set of indicator variables have been constructed:

- *lt_hs*: less than a high school diploma, 1 if $educ < 12$, 0 otherwise,
- *hs*: a high school diploma, 1 if $educ = 12$, 0 otherwise,
- *some_col*: some college, 1 if $12 < educ < 16$, 0 otherwise,
- *college*: bachelor's degree or higher, 1 if $educ \geq 16$, 0 otherwise.

Question 1 (35 marks)

(a) In order to investigate the relationship between earnings and height, a simple OLS regression of *earnings* on *height* has been carried out. The regression output is reported in Table 1. Interpret the estimated coefficient on *height*. Is the sign of the coefficient on *height* as expected?

(6 marks)

(b) Construct a 95% and a 99% confidence interval for the coefficient on *height*. **(4 marks)**

(c) Formally test whether the coefficient on *height* is statistically significant at the 1% and 5% significance level. State your null and alternative hypothesis. Use t-values, p-values and confidence intervals to carry out the test in three equivalent ways. **(6 marks)**

(d) Interpret the OLS estimate of the intercept in Table 1. Does the intercept have a real life meaning? **(3 marks)**

(e) Comment on the measures of fit reported in Table 1. Would you say the regression fits well? **(4 marks)**

(f) The regression of *earnings* on *height* has been re-estimated using data for female workers only. The regression output is reported in Table 2. For a woman who is 1 inch taller than the average woman in the sample, would you predict her earnings to be higher or lower than the average earnings for women in the sample? By how much? **(6 marks)**

(g) The regression of *earnings* on *height* has also been re-estimated using data for male workers only. The regression output is reported in Table 3. Test the hypothesis that the effect of height on earnings is the same for men and women. **(6 marks)**

turn over

Table 1

```
> regr1 <- lm(earnings ~ height, data = earn)
> summary(regr1)

Call:
lm(formula = earnings ~ height, data = earn)

Residuals:
   Min     1Q Median     3Q    Max
-47836 -21879  -7976  34323  50599

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  -512.73    3386.86  -0.151     0.88
height        707.67      50.49          <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 26780 on 17868 degrees of freedom
Multiple R-squared:  0.01088,	Adjusted R-squared:  0.01082
F-statistic: 196.5 on 1 and 17868 DF,  p-value: < 2.2e-16


> coeftest(regr1, vcovHC(regr1, type = "HC1"))

t test of coefficients:

            Estimate Std. Error t value Pr(>|t|)
(Intercept) -512.734   3379.864 -0.1517   0.8794
height       707.672     50.395          <2e-16 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Table 2

```
> regr2 <- lm(earnings ~ height, data = filter(earn, sex == 0))
> summary(regr2)
```

```
> coeftest(regr2, vcovHC(regr2, type = "HC1"))

t test of coefficients:

             Estimate Std. Error t value Pr(>|t|)
(Intercept) 12650.858   6299.151  2.0083  0.04463 *
height        511.222     97.585  5.2388 1.65e-07 ***
---
Signif. codes:  0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Table 3

```
> regr3 <- lm(earnings ~ height, data = filter(earn, sex == 1))
> summary(regr3)
```

```
> coeftest(regr3, vcovHC(regr3, type = "HC1"))

t test of coefficients:

              Estimate Std. Error t value  Pr(>|t|)
(Intercept) -43130.342   6925.011 -6.2282  4.96e-10 ***
height        1306.860     98.857 13.2197 < 2.2e-16 ***
---
Signif. codes:
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

turn over

Question 2 (40 marks)

In Question 1, you estimated a relatively large and statistically significant effect of a worker's height on his or her earnings. One explanation for this result is omitted variable bias: Height is correlated with an omitted variable that affects earnings. For example, Case and Paxson (2008) suggest that cognitive ability (or intelligence) is the omitted variable. The mechanism they describe is straightforward: Poor nutrition and other harmful environmental factors in utero and in early childhood have, on average, deleterious effects on both cognitive and physical development. Cognitive ability affects earnings later in life and thus is an omitted variable in the regression.

(a) Suppose that the mechanism described above is correct. Explain how this leads to omitted variable bias in the OLS regression of *earnings* on *height*. Does the bias lead the estimated slope to be too large or too small? **(5 marks)**

If the mechanism described above is correct, the estimated effect of height on earnings should disappear if a variable measuring cognitive ability is included in the regression. Unfortunately, there isn't a direct measure of cognitive ability in the data set, but the data set does include years of education for each individual. Because students with higher cognitive ability are more likely to attend school longer, years of education might serve as a control variable for cognitive ability; in this case, including education in the regression will eliminate, or at least attenuate, the omitted variable bias problem.

(b) A regression of *earnings* on *height*, *lt_hs*, *hs* and *some_col* has been estimated. The results are reported in Table 4. Compare the estimated coefficient on *height* in Tables 1 and 4. Is there a large change in the coefficient? Has it changed in a way consistent with the cognitive ability explanation? Explain. **(5 marks)**

(c) The regression omits the control variable *college*. Why? **(4 marks)**

(d) Are the coefficients on the education variables individually significant?

(5 marks)

(e) Test the joint null hypothesis that the coefficients on the education variables are equal to 0. You may use results reported in Table 5.

(5 marks)

(f) What do the coefficients on lt_hs, hs and $some\_col$ measure? Carefully interpret the estimated coefficients and discuss their values.

(6 marks)

(g) To explore possible nonlinearities in the relation between average earnings and education, a regression of *earnings* on *height*, *educ*, $educ^2$ and $educ^3$ have been estimated and a suitable hypothesis has been tested. The regression output and the results of the test are reported in Tables 6 and 7. Looking at these results, would you say that the effect of education on earnings is nonlinear? Justify your answer. **(5 marks)**

(h) Considering all of the above results, does the analysis suggest that there is gender earning gap? That is, ceteris paribus, do females have lower average hourly earnings than men? Is a conclusion based on the reported results reliable? **(5 marks)**

turn over

Table 4

```
> regr4 <- lm(earnings ~ height + lt_hs + hs + some_col, data =
earn)
> summary(regr4)

Call:
lm(formula = earnings ~ height + lt_hs + hs + some_col, data = e
arn)

Residuals:
   Min     1Q Median     3Q    Max
-57726 -19154  -6081  22510  63756

Coefficients:
            Estimate Std. Error t value Pr(>|t|)
(Intercept)  30233.1     3188.8   9.481   <2e-16 ***
height         453.8       47.0   9.656   <2e-16 ***
lt_hs       -31716.1      682.2 -46.489   <2e-16 ***
hs          -20389.4      464.4 -43.902   <2e-16 ***
some_col    -12643.0      508.4 -24.866   <2e-16 ***
---
Signif. codes:
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 24800 on 17865 degrees of freedom
Multiple R-squared:  0.1517,    Adjusted R-squared:  0.1516
F-statistic:   799 on 4 and 17865 DF,  p-value: < 2.2e-16


> coeftest(regr4, vcovHC(regr4, type = "HC1"))

t test of coefficients:

              Estimate Std. Error  t value  Pr(>|t|)
(Intercept)  30233.090   3199.425   9.4495 < 2.2e-16 ***
height         453.793     47.029   9.6492 < 2.2e-16 ***
lt_hs       -31716.086    595.609 -53.2498 < 2.2e-16 ***
hs          -20389.410    471.775 -43.2185 < 2.2e-16 ***
some_col    -12643.006    533.005 -23.7203 < 2.2e-16 ***
---
Signif. codes:
0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
```

Table 5

```
> linearHypothesis(regr4, c("lt_hs", "hs", "some_col"), white.ad
just = "hc1")

Linear hypothesis test:
lt_hs = 0
hs = 0
some_col = 0

Model 1: restricted model
Model 2: earnings ~ height + lt_hs + hs + some_col

Note: Coefficient covariance matrix supplied.

  Res.Df Df      F    Pr(>F)
1  17868
2  17865  3 1100.6 < 2.2e-16 ***
---
Signif. codes:
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

turn over

Table 6

```
> regr5 <- lm(earnings ~ height + educ + I(educ^2) + I(educ^3),
data = earn)
> summary(regr5)

Call:
lm(formula = earnings ~ height + educ + I(educ^2) + I(educ^3),
    data = earn)

Residuals:
   Min     1Q Median     3Q    Max
-61063 -19259  -5852  20955  71743

Coefficients:
             Estimate Std. Error t value Pr(>|t|)
(Intercept)  1772.402   4829.016   0.367    0.714
height        416.718     46.884   8.888  < 2e-16 ***
educ        -4811.526   1107.736  -4.344 1.41e-05 ***
I(educ^2)     663.344    105.020   6.316 2.74e-10 ***
I(educ^3)     -15.911      3.098  -5.136 2.84e-07 ***
---
Signif. codes:
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1

Residual standard error: 24690 on 17865 degrees of freedom
Multiple R-squared:  0.1591,    Adjusted R-squared:  0.1589
F-statistic: 844.9 on 4 and 17865 DF,  p-value: < 2.2e-16
```

```
> coeftest(regr5, vcovHC(regr5, type = "HC1"))

t test of coefficients:

              Estimate Std. Error t value  Pr(>|t|)
(Intercept)  1772.4019  4092.0463  0.4331    0.6649
height        416.7176    46.9929  8.8677 < 2.2e-16 ***
educ        -4811.5259   907.8258 -5.3001 1.171e-07 ***
I(educ^2)     663.3441    90.0392  7.3673 1.817e-13 ***
I(educ^3)     -15.9109     2.7236 -5.8420 5.249e-09 ***
---
Signif. codes:
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

Table 7

```
> linearHypothesis(regr5, c("educ", "I(educ^2)", "I(educ^3)"), w
hite.adjust = "hc1")

Linear hypothesis test:
educ = 0
I(educ^2) = 0
I(educ^3) = 0

Model 1: restricted model
Model 2: earnings ~ height + educ + I(educ^2) + I(educ^3)

Note: Coefficient covariance matrix supplied.

  Res.Df Df      F    Pr(>F)
1  17868
2  17865  3 1197.4 < 2.2e-16 ***
---
Signif. codes:
0 ‘***’ 0.001 ‘**’ 0.01 ‘*’ 0.05 ‘.’ 0.1 ‘ ’ 1
```

turn over

Question 3 (25 marks)

(a) Suppose that, in a randomized controlled experiment of the effect of an SAT preparatory course on SAT scores, the following results are reported:

	Treatment Group	Control Group
Average SAT score ($\bar{X}$)	1393	1342
Standard deviation of SAT score (σ_X)	84.3	80.1
Number of men	45	55
Number of women	55	45

Estimate the average treatment effect on test scores. **(4 marks)**

(b) Is there evidence of nonrandom assignment? Explain. **(8 marks)**

Parts (c) and (d) below discuss some of the results of the Project STAR. This project was a randomized control trial where both students and teachers were randomly assigned to one of three types of classes. The following regression has been estimated for a sample of 5766 students of the first grade:

$$\widehat{TestScore}_i = \underset{(4.25)}{14.00} SmallClass_i - \underset{(3.84)}{0.60} RegAide_i$$

$$+\underset{(0.44)}{1.74} Exper_i, \quad \bar{R}^2 = 0.02,$$

where robustly estimated standard errors of estimated coefficients are reported in parentheses. Indicator variable *SmallClass* is 1 for classes of size 13 to 17 students, 0 otherwise. Indicator variable *RegAide* is 1 for regular classes of size 22 to 25 students, single teacher and an aide, and 0 otherwise. Indicator variable *Reg* is 1 for regular sized classes of 22 to 25 students, with single teacher and no aide and 0 otherwise. Variable *Exper* is teacher's years of experience.
The regression also included school indicator variables and an intercept (not reported).

(c) Consider two classrooms, 1 and 2, which have teachers with the same number of years of experience. Classroom 1 is a small class, and classroom 2 is a regular-sized class. Construct a 95% confidence interval for the expected difference in average test scores of the two classrooms.

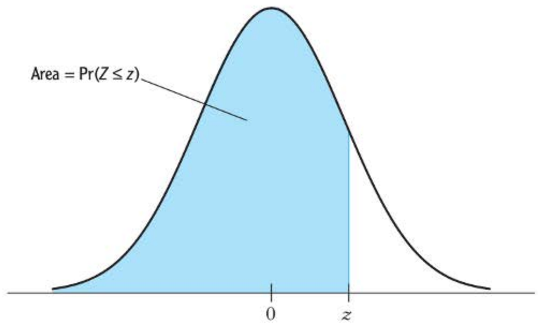
(5 marks)

(d) Classroom 1 is a small-sized class with a teacher with 5 years of experience, and classroom 2 is a regular-sized class with a teacher with 14 years of experience. Construct a 90% confidence interval for the expected difference in average test scores of the two classrooms.

Hint: Recall that in STAR, the teachers were randomly assigned to the different types of classrooms. **(8 marks)**

End of Paper - An Appendix of 3 pages follows

TABLE 1 The Cumulative Standard Normal Distribution Function, $\Phi(z) = \Pr(Z \leq z)$



	Second Decimal Value of z									
z	0	1	2	3	4	5	6	7	8	9
–2.9	0.0019	0.0018	0.0018	0.0017	0.0016	0.0016	0.0015	0.0015	0.0014	0.0014
–2.8	0.0026	0.0025	0.0024	0.0023	0.0023	0.0022	0.0021	0.0021	0.0020	0.0019
–2.7	0.0035	0.0034	0.0033	0.0032	0.0031	0.0030	0.0029	0.0028	0.0027	0.0026
–2.6	0.0047	0.0045	0.0044	0.0043	0.0041	0.0040	0.0039	0.0038	0.0037	0.0036
–2.5	0.0062	0.0060	0.0059	0.0057	0.0055	0.0054	0.0052	0.0051	0.0049	0.0048
–2.4	0.0082	0.0080	0.0078	0.0075	0.0073	0.0071	0.0069	0.0068	0.0066	0.0064
–2.3	0.0107	0.0104	0.0102	0.0099	0.0096	0.0094	0.0091	0.0089	0.0087	0.0084
–2.2	0.0139	0.0136	0.0132	0.0129	0.0125	0.0122	0.0119	0.0116	0.0113	0.0110
–2.1	0.0179	0.0174	0.0170	0.0166	0.0162	0.0158	0.0154	0.0150	0.0146	0.0143
–2.0	0.0228	0.0222	0.0217	0.0212	0.0207	0.0202	0.0197	0.0192	0.0188	0.0183
–1.9	0.0287	0.0281	0.0274	0.0268	0.0262	0.0256	0.0250	0.0244	0.0239	0.0233
–1.8	0.0359	0.0351	0.0344	0.0336	0.0329	0.0322	0.0314	0.0307	0.0301	0.0294
–1.7	0.0446	0.0436	0.0427	0.0418	0.0409	0.0401	0.0392	0.0384	0.0375	0.0367
–1.6	0.0548	0.0537	0.0526	0.0516	0.0505	0.0495	0.0485	0.0475	0.0465	0.0455
–1.5	0.0668	0.0655	0.0643	0.0630	0.0618	0.0606	0.0594	0.0582	0.0571	0.0559
–1.4	0.0808	0.0793	0.0778	0.0764	0.0749	0.0735	0.0721	0.0708	0.0694	0.0681
–1.3	0.0968	0.0951	0.0934	0.0918	0.0901	0.0885	0.0869	0.0853	0.0838	0.0823
–1.2	0.1151	0.1131	0.1112	0.1093	0.1075	0.1056	0.1038	0.1020	0.1003	0.0985
–1.1	0.1357	0.1335	0.1314	0.1292	0.1271	0.1251	0.1230	0.1210	0.1190	0.1170
–1.0	0.1587	0.1562	0.1539	0.1515	0.1492	0.1469	0.1446	0.1423	0.1401	0.1379
–0.9	0.1841	0.1814	0.1788	0.1762	0.1736	0.1711	0.1685	0.1660	0.1635	0.1611

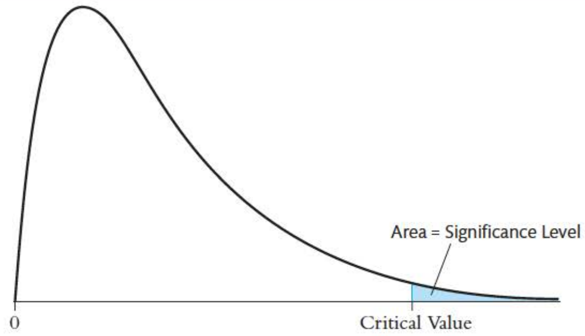
(Table 1 continued)

(Table 1 continued)

z	Second Decimal Value of z 0	1	2	3	4	5	6	7	8	9
−0.8	0.2119	0.2090	0.2061	0.2033	0.2005	0.1977	0.1949	0.1922	0.1894	0.1867
−0.7	0.2420	0.2389	0.2358	0.2327	0.2296	0.2266	0.2236	0.2206	0.2177	0.2148
−0.6	0.2743	0.2709	0.2676	0.2643	0.2611	0.2578	0.2546	0.2514	0.2483	0.2451
−0.5	0.3085	0.3050	0.3015	0.2981	0.2946	0.2912	0.2877	0.2843	0.2810	0.2776
−0.4	0.3446	0.3409	0.3372	0.3336	0.3300	0.3264	0.3228	0.3192	0.3156	0.3121
−0.3	0.3821	0.3783	0.3745	0.3707	0.3669	0.3632	0.3594	0.3557	0.3520	0.3483
−0.2	0.4207	0.4168	0.4129	0.4090	0.4052	0.4013	0.3974	0.3936	0.3897	0.3859
−0.1	0.4602	0.4562	0.4522	0.4483	0.4443	0.4404	0.4364	0.4325	0.4286	0.4247
−0.0	0.5000	0.4960	0.4920	0.4880	0.4840	0.4801	0.4761	0.4721	0.4681	0.4641
0.0	0.5000	0.5040	0.5080	0.5120	0.5160	0.5199	0.5239	0.5279	0.5319	0.5359
0.1	0.5398	0.5438	0.5478	0.5517	0.5557	0.5596	0.5636	0.5675	0.5714	0.5753
0.2	0.5793	0.5832	0.5871	0.5910	0.5948	0.5987	0.6026	0.6064	0.6103	0.6141
0.3	0.6179	0.6217	0.6255	0.6293	0.6331	0.6368	0.6406	0.6443	0.6480	0.6517
0.4	0.6554	0.6591	0.6628	0.6664	0.6700	0.6736	0.6772	0.6808	0.6844	0.6879
0.5	0.6915	0.6950	0.6985	0.7019	0.7054	0.7088	0.7123	0.7157	0.7190	0.7224
0.6	0.7257	0.7291	0.7324	0.7357	0.7389	0.7422	0.7454	0.7486	0.7517	0.7549
0.7	0.7580	0.7611	0.7642	0.7673	0.7704	0.7734	0.7764	0.7794	0.7823	0.7852
0.8	0.7881	0.7910	0.7939	0.7967	0.7995	0.8023	0.8051	0.8078	0.8106	0.8133
0.9	0.8159	0.8186	0.8212	0.8238	0.8264	0.8289	0.8315	0.8340	0.8365	0.8389
1.0	0.8413	0.8438	0.8461	0.8485	0.8508	0.8531	0.8554	0.8577	0.8599	0.8621
1.1	0.8643	0.8665	0.8686	0.8708	0.8729	0.8749	0.8770	0.8790	0.8810	0.8830
1.2	0.8849	0.8869	0.8888	0.8907	0.8925	0.8944	0.8962	0.8980	0.8997	0.9015
1.3	0.9032	0.9049	0.9066	0.9082	0.9099	0.9115	0.9131	0.9147	0.9162	0.9177
1.4	0.9192	0.9207	0.9222	0.9236	0.9251	0.9265	0.9279	0.9292	0.9306	0.9319
1.5	0.9332	0.9345	0.9357	0.9370	0.9382	0.9394	0.9406	0.9418	0.9429	0.9441
1.6	0.9452	0.9463	0.9474	0.9484	0.9495	0.9505	0.9515	0.9525	0.9535	0.9545
1.7	0.9554	0.9564	0.9573	0.9582	0.9591	0.9599	0.9608	0.9616	0.9625	0.9633
1.8	0.9641	0.9649	0.9656	0.9664	0.9671	0.9678	0.9686	0.9693	0.9699	0.9706
1.9	0.9713	0.9719	0.9726	0.9732	0.9738	0.9744	0.9750	0.9756	0.9761	0.9767
2.0	0.9772	0.9778	0.9783	0.9788	0.9793	0.9798	0.9803	0.9808	0.9812	0.9817
2.1	0.9821	0.9826	0.9830	0.9834	0.9838	0.9842	0.9846	0.9850	0.9854	0.9857
2.2	0.9861	0.9864	0.9868	0.9871	0.9875	0.9878	0.9881	0.9884	0.9887	0.9890
2.3	0.9893	0.9896	0.9898	0.9901	0.9904	0.9906	0.9909	0.9911	0.9913	0.9916
2.4	0.9918	0.9920	0.9922	0.9925	0.9927	0.9929	0.9931	0.9932	0.9934	0.9936
2.5	0.9938	0.9940	0.9941	0.9943	0.9945	0.9946	0.9948	0.9949	0.9951	0.9952
2.6	0.9953	0.9955	0.9956	0.9957	0.9959	0.9960	0.9961	0.9962	0.9963	0.9964
2.7	0.9965	0.9966	0.9967	0.9968	0.9969	0.9970	0.9971	0.9972	0.9973	0.9974
2.8	0.9974	0.9975	0.9976	0.9977	0.9977	0.9978	0.9979	0.9979	0.9980	0.9981
2.9	0.9981	0.9982	0.9982	0.9983	0.9984	0.9984	0.9985	0.9985	0.9986	0.9986

This table can be used to calculate $\Pr(Z \leq z)$ where Z is a standard normal variable. For example, when $z = 1.17$, this probability is 0.8790, which is the table entry for the row labeled 1.1 and the column labeled 7.

TABLE 4 Critical Values for the $F_{m,\infty}$ Distribution



Degrees of Freedom	Significance Level 10%	5%	1%
1	2.71	3.84	6.63
2	2.30	3.00	4.61
3	2.08	2.60	3.78
4	1.94	2.37	3.32
5	1.85	2.21	3.02
6	1.77	2.10	2.80
7	1.72	2.01	2.64
8	1.67	1.94	2.51
9	1.63	1.88	2.41
10	1.60	1.83	2.32
11	1.57	1.79	2.25
12	1.55	1.75	2.18
13	1.52	1.72	2.13
14	1.50	1.69	2.08
15	1.49	1.67	2.04
16	1.47	1.64	2.00
17	1.46	1.62	1.97
18	1.44	1.60	1.93
19	1.43	1.59	1.90
20	1.42	1.57	1.88
21	1.41	1.56	1.85
22	1.40	1.54	1.83
23	1.39	1.53	1.81
24	1.38	1.52	1.79
25	1.38	1.51	1.77
26	1.37	1.50	1.76
27	1.36	1.49	1.74
28	1.35	1.48	1.72
29	1.35	1.47	1.71
30	1.34	1.46	1.70

This table contains the 90th, 95th, and 99th percentiles of the $F_{m,\infty}$ distribution. These serve as critical values for tests with significance levels of 10%, 5%, and 1%.

End of Appendix