**Continuous Assessment in Applied Econometrics – 2H**

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*Master 1 – Mock exam 2*

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Answer the questions in order. All answers must be justified. Calculators are allowed. Throughout, log denotes the natural logarithm. Unless stated otherwise, the assumptions of the classical linear model, including normally distributed errors, are taken to hold. Critical values are read from the tables at the end of the paper. When the number of degrees of freedom is not printed, use the closest lower row, and use the row $\infty$ above 120. The marking scheme is indicative.

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### Exercise 1: Days at sea and catches of a trawler fleet *(5 points)*

A fishermen's cooperative in Brittany records, for $N = 12$ trawlers, the number of days spent at sea in October 2026 ($x_i$) and the catch ($y_i$, in tonnes). For the model $y = X\beta + u$, where the columns of $X$ are a constant and $x$, the cooperative's software prints:

$$X'X = \begin{pmatrix} 12 & 216 \\ 216 & 4{,}104 \end{pmatrix}, \qquad X'y = \begin{pmatrix} 360 \\ 6{,}804 \end{pmatrix}, \qquad y'y = 11{,}346.$$

**1.** Compute $(X'X)^{-1}$ and $\hat{\beta} = (X'X)^{-1}X'y$. Interpret $\hat{\beta}_1$.

**2.** Let $M = I - X(X'X)^{-1}X'$, so that the residual vector is $\hat{u} = My$. Using the fact that $M$ is symmetric and idempotent, show that $\hat{u}'\hat{u} = y'y - \hat{\beta}'X'y$. Deduce the sum of squared residuals without computing any residual.

**3.** Compute $\hat{\sigma}^2$, the estimated variance matrix $\hat{\sigma}^2(X'X)^{-1}$, and the standard errors of $\hat{\beta}_0$ and $\hat{\beta}_1$.

**4.** A regional fisheries report states that one more day at sea yields 2 tonnes on average. Test this statement at the 5% level against a two-sided alternative.

**5.** Suppose that all trawlers had spent exactly 18 days at sea. Write $X'X$ in that case and explain, in two or three lines, why $\beta_1$ could not be estimated.

### Exercise 2: Who consumes electricity? *(6 points)*

An energy regulator studies the annual electricity consumption of 800 French households. The dependent variable is the log of annual consumption (kWh). The regressors are the log of the household's annual disposable income (euros), the log of the dwelling's surface ($\text{m}^2$), *eheat*, a dummy equal to 1 if the dwelling has electric heating, and *occ*, the number of occupants. Column (4) reports the regression of $\log(surf)$ on a constant and $\log(inc)$.

**Table 1 – Household electricity consumption, OLS estimates**

| Dependent variable | (1) $\log(kwh)$ | (2) $\log(kwh)$ | (3) $\log(kwh)$ | (4) $\log(surf)$ |
|---|---|---|---|---|
| $\log(inc)$ | 0.349 | 0.079 | 0.056 | 0.377 |
| | (0.043) | (0.044) | (0.037) | (0.025) |
| $\log(surf)$ | | 0.716 | 0.736 | |
| | | (0.056) | (0.047) | |
| *eheat* | | | 0.469 | |
| | | | (0.030) | |
| *occ* | | | 0.106 | |
| | | | (0.010) | |
| Constant | 4.799 | 4.486 | 4.154 | 0.437 |
| | (0.450) | (0.410) | (0.344) | (0.261) |
| $N$ | 800 | 800 | 800 | 800 |
| $R^2$ | 0.076 | 0.235 | 0.468 | 0.224 |

*Notes:* standard errors in parentheses.

We denote by $\tilde{\beta}_1$ the coefficient on $\log(inc)$ in column (1), by $\hat{\beta}_1$ and $\hat{\beta}_2$ the coefficients on $\log(inc)$ and $\log(surf)$ in column (2), and by $\tilde{\delta}_1$ the coefficient on $\log(inc)$ in column (4).

1. Write the estimated equation of column (2). Interpret the coefficients on $\log(inc)$ and on $\log(surf)$.
2. In column (2), test at the 5% level the hypothesis that income has no effect on consumption for a given surface, against a two-sided alternative. Same question at the 10% level.
3. Using only the $R^2$ of column (2), test at the 5% level the joint significance of its regressors.
4. Test at the 5% level whether *eheat* and *occ* can be jointly excluded from column (3). Give the exact percentage effect of electric heating.
5. (a) Interpret $\tilde{\delta}_1$.
   (b) Verify numerically the relation $\tilde{\beta}_1 = \hat{\beta}_1 + \hat{\beta}_2\tilde{\delta}_1$.
   (c) Is the income elasticity overestimated or underestimated in column (1)? By how much? Explain in one sentence.
6. On the basis of column (1), a newspaper writes: "a 10% rise in income raises a household's electricity consumption by 3.5%". Comment in two or three lines.

**Exercise 3: Waste per inhabitant and the size of municipalities** ***(4 points)***

Two analysts of a regional waste agency use the same data on $N = 200$ municipalities. Analyst A estimates by OLS:

$$\widehat{\log(waste)} = \underset{(0.48)}{-1.43} + \underset{(0.05)}{1.08}\log(pop), \qquad R^2 = 0.702, \qquad \text{SSR} = 17.82,$$

where *waste* is the household waste collected (tonnes per year) and *pop* the number of inhabitants. Analyst B regresses $\log(waste/pop)$, the log of waste per inhabitant, on a constant and $\log(pop)$.

1. Without re-estimating, give the intercept, the slope, the standard error of the slope and the SSR of analyst B's regression. Justify each answer.
2. Interpret the slope of analyst A and the slope of analyst B.
3. Test at the 5% level the hypothesis that waste per inhabitant does not depend on the size of the municipality, against a two-sided alternative. To which hypothesis on analyst A's slope is it equivalent?

4. Analyst B reports $R^2 = 0.013$. Analyst A concludes: "my model explains 70% of the variance and B's model almost nothing, so B's model is worse". Compute the total sum of squares of each regression and explain why A's conclusion is wrong.

5. An intern proposes to test the hypothesis of question 3 with $F = \dfrac{(0.702 - 0.013)/1}{(1 - 0.702)/198}$. Explain in two or three lines why this statistic is meaningless.

**Exercise 4: How much do Parisians tip?** ***(5 points)***

A restaurant chain in Paris records, for $N = 250$ tables, the bill (euros, between 15 and 180) and the tip left by the customers (euros). It estimates by OLS (standard errors in parentheses):

$$\widehat{tip} = \underset{(0.30)}{0.80} + \underset{(0.007)}{0.100}\, bill, \qquad R^2 = 0.45.$$

1. Interpret the slope and the intercept.

2. Write the predicted average tip rate $\widehat{tip}/bill$ as a function of the bill, and compute it for bills of 20 and 100 euros. With the bill on the horizontal axis, sketch the marginal and the average tip rates, and compare them.

3. A guidebook states that "Parisian diners tip 12% of the bill". Write the two restrictions this statement imposes on $\beta_0$ and $\beta_1$, and test each of them separately at the 5% level against a two-sided alternative.

4. The dispersion of tips increases with the bill. Which assumption fails? What are the consequences for the OLS estimates and for the tests of question 3?

5. Is 0.100 the causal effect of a higher bill on the tip? Give two factors contained in the error term and the plausible direction of the bias.

**TABLE G.2 Critical Values of the *t* Distribution**

| | | Significance Level | | | | |
|---|---|---|---|---|---|---|
| 1-Tailed: | | .10 | .05 | .025 | .01 | .005 |
| 2-Tailed: | | .20 | .10 | .05 | .02 | .01 |
| Degrees of Freedom | 1 | 3.078 | 6.314 | 12.706 | 31.821 | 63.657 |
| | 2 | 1.886 | 2.920 | 4.303 | 6.965 | 9.925 |
| | 3 | 1.638 | 2.353 | 3.182 | 4.541 | 5.841 |
| | 4 | 1.533 | 2.132 | 2.776 | 3.747 | 4.604 |
| | 5 | 1.476 | 2.015 | 2.571 | 3.365 | 4.032 |
| | 6 | 1.440 | 1.943 | 2.447 | 3.143 | 3.707 |
| | 7 | 1.415 | 1.895 | 2.365 | 2.998 | 3.499 |
| | 8 | 1.397 | 1.860 | 2.306 | 2.896 | 3.355 |
| | 9 | 1.383 | 1.833 | 2.262 | 2.821 | 3.250 |
| | 10 | 1.372 | 1.812 | 2.228 | 2.764 | 3.169 |
| | 11 | 1.363 | 1.796 | 2.201 | 2.718 | 3.106 |
| | 12 | 1.356 | 1.782 | 2.179 | 2.681 | 3.055 |
| | 13 | 1.350 | 1.771 | 2.160 | 2.650 | 3.012 |
| | 14 | 1.345 | 1.761 | 2.145 | 2.624 | 2.977 |
| | 15 | 1.341 | 1.753 | 2.131 | 2.602 | 2.947 |
| | 16 | 1.337 | 1.746 | 2.120 | 2.583 | 2.921 |
| | 17 | 1.333 | 1.740 | 2.110 | 2.567 | 2.898 |
| | 18 | 1.330 | 1.734 | 2.101 | 2.552 | 2.878 |
| | 19 | 1.328 | 1.729 | 2.093 | 2.539 | 2.861 |
| | 20 | 1.325 | 1.725 | 2.086 | 2.528 | 2.845 |
| | 21 | 1.323 | 1.721 | 2.080 | 2.518 | 2.831 |
| | 22 | 1.321 | 1.717 | 2.074 | 2.508 | 2.819 |
| | 23 | 1.319 | 1.714 | 2.069 | 2.500 | 2.807 |
| | 24 | 1.318 | 1.711 | 2.064 | 2.492 | 2.797 |
| | 25 | 1.316 | 1.708 | 2.060 | 2.485 | 2.787 |
| | 26 | 1.315 | 1.706 | 2.056 | 2.479 | 2.779 |
| | 27 | 1.314 | 1.703 | 2.052 | 2.473 | 2.771 |
| | 28 | 1.313 | 1.701 | 2.048 | 2.467 | 2.763 |
| | 29 | 1.311 | 1.699 | 2.045 | 2.462 | 2.756 |
| | 30 | 1.310 | 1.697 | 2.042 | 2.457 | 2.750 |
| | 40 | 1.303 | 1.684 | 2.021 | 2.423 | 2.704 |
| | 60 | 1.296 | 1.671 | 2.000 | 2.390 | 2.660 |
| | 90 | 1.291 | 1.662 | 1.987 | 2.368 | 2.632 |
| | 120 | 1.289 | 1.658 | 1.980 | 2.358 | 2.617 |
| | ∞ | 1.282 | 1.645 | 1.960 | 2.326 | 2.576 |

Examples: The 1% critical value for a one-tailed test with 25 *df* is 2.485. The 5% critical value for a two-tailed test with large ($> 120$) *df* is 1.96.

*Source*: This table was generated using the Stata® function invttail.

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**TABLE G.3a 10% Critical Values of the *F* Distribution**

| | | Numerator Degrees of Freedom | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Denominator Degrees of Freedom | 10 | 3.29 | 2.92 | 2.73 | 2.61 | 2.52 | 2.46 | 2.41 | 2.38 | 2.35 | 2.32 |
| | 11 | 3.23 | 2.86 | 2.66 | 2.54 | 2.45 | 2.39 | 2.34 | 2.30 | 2.27 | 2.25 |
| | 12 | 3.18 | 2.81 | 2.61 | 2.48 | 2.39 | 2.33 | 2.28 | 2.24 | 2.21 | 2.19 |
| | 13 | 3.14 | 2.76 | 2.56 | 2.43 | 2.35 | 2.28 | 2.23 | 2.20 | 2.16 | 2.14 |
| | 14 | 3.10 | 2.73 | 2.52 | 2.39 | 2.31 | 2.24 | 2.19 | 2.15 | 2.12 | 2.10 |
| | 15 | 3.07 | 2.70 | 2.49 | 2.36 | 2.27 | 2.21 | 2.16 | 2.12 | 2.09 | 2.06 |
| | 16 | 3.05 | 2.67 | 2.46 | 2.33 | 2.24 | 2.18 | 2.13 | 2.09 | 2.06 | 2.03 |
| | 17 | 3.03 | 2.64 | 2.44 | 2.31 | 2.22 | 2.15 | 2.10 | 2.06 | 2.03 | 2.00 |
| | 18 | 3.01 | 2.62 | 2.42 | 2.29 | 2.20 | 2.13 | 2.08 | 2.04 | 2.00 | 1.98 |
| | 19 | 2.99 | 2.61 | 2.40 | 2.27 | 2.18 | 2.11 | 2.06 | 2.02 | 1.98 | 1.96 |
| | 20 | 2.97 | 2.59 | 2.38 | 2.25 | 2.16 | 2.09 | 2.04 | 2.00 | 1.96 | 1.94 |
| | 21 | 2.96 | 2.57 | 2.36 | 2.23 | 2.14 | 2.08 | 2.02 | 1.98 | 1.95 | 1.92 |
| | 22 | 2.95 | 2.56 | 2.35 | 2.22 | 2.13 | 2.06 | 2.01 | 1.97 | 1.93 | 1.90 |
| | 23 | 2.94 | 2.55 | 2.34 | 2.21 | 2.11 | 2.05 | 1.99 | 1.95 | 1.92 | 1.89 |
| | 24 | 2.93 | 2.54 | 2.33 | 2.19 | 2.10 | 2.04 | 1.98 | 1.94 | 1.91 | 1.88 |
| | 25 | 2.92 | 2.53 | 2.32 | 2.18 | 2.09 | 2.02 | 1.97 | 1.93 | 1.89 | 1.87 |
| | 26 | 2.91 | 2.52 | 2.31 | 2.17 | 2.08 | 2.01 | 1.96 | 1.92 | 1.88 | 1.86 |
| | 27 | 2.90 | 2.51 | 2.30 | 2.17 | 2.07 | 2.00 | 1.95 | 1.91 | 1.87 | 1.85 |
| | 28 | 2.89 | 2.50 | 2.29 | 2.16 | 2.06 | 2.00 | 1.94 | 1.90 | 1.87 | 1.84 |
| | 29 | 2.89 | 2.50 | 2.28 | 2.15 | 2.06 | 1.99 | 1.93 | 1.89 | 1.86 | 1.83 |
| | 30 | 2.88 | 2.49 | 2.28 | 2.14 | 2.05 | 1.98 | 1.93 | 1.88 | 1.85 | 1.82 |
| | 40 | 2.84 | 2.44 | 2.23 | 2.09 | 2.00 | 1.93 | 1.87 | 1.83 | 1.79 | 1.76 |
| | 60 | 2.79 | 2.39 | 2.18 | 2.04 | 1.95 | 1.87 | 1.82 | 1.77 | 1.74 | 1.71 |
| | 90 | 2.76 | 2.36 | 2.15 | 2.01 | 1.91 | 1.84 | 1.78 | 1.74 | 1.70 | 1.67 |
| | 120 | 2.75 | 2.35 | 2.13 | 1.99 | 1.90 | 1.82 | 1.77 | 1.72 | 1.68 | 1.65 |
| | ∞ | 2.71 | 2.30 | 2.08 | 1.94 | 1.85 | 1.77 | 1.72 | 1.67 | 1.63 | 1.60 |

Example: The 10% critical value for numerator $df = 2$ and denominator $df = 40$ is 2.44.
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**TABLE G.3b 5% Critical Values of the *F* Distribution**

| | | Numerator Degrees of Freedom | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
| Denominator Degrees of Freedom | 10 | 4.96 | 4.10 | 3.71 | 3.48 | 3.33 | 3.22 | 3.14 | 3.07 | 3.02 | 2.98 |
| | 11 | 4.84 | 3.98 | 3.59 | 3.36 | 3.20 | 3.09 | 3.01 | 2.95 | 2.90 | 2.85 |
| | 12 | 4.75 | 3.89 | 3.49 | 3.26 | 3.11 | 3.00 | 2.91 | 2.85 | 2.80 | 2.75 |
| | 13 | 4.67 | 3.81 | 3.41 | 3.18 | 3.03 | 2.92 | 2.83 | 2.77 | 2.71 | 2.67 |
| | 14 | 4.60 | 3.74 | 3.34 | 3.11 | 2.96 | 2.85 | 2.76 | 2.70 | 2.65 | 2.60 |
| | 15 | 4.54 | 3.68 | 3.29 | 3.06 | 2.90 | 2.79 | 2.71 | 2.64 | 2.59 | 2.54 |
| | 16 | 4.49 | 3.63 | 3.24 | 3.01 | 2.85 | 2.74 | 2.66 | 2.59 | 2.54 | 2.49 |
| | 17 | 4.45 | 3.59 | 3.20 | 2.96 | 2.81 | 2.70 | 2.61 | 2.55 | 2.49 | 2.45 |
| | 18 | 4.41 | 3.55 | 3.16 | 2.93 | 2.77 | 2.66 | 2.58 | 2.51 | 2.46 | 2.41 |
| | 19 | 4.38 | 3.52 | 3.13 | 2.90 | 2.74 | 2.63 | 2.54 | 2.48 | 2.42 | 2.38 |
| | 20 | 4.35 | 3.49 | 3.10 | 2.87 | 2.71 | 2.60 | 2.51 | 2.45 | 2.39 | 2.35 |
| | 21 | 4.32 | 3.47 | 3.07 | 2.84 | 2.68 | 2.57 | 2.49 | 2.42 | 2.37 | 2.32 |
| | 22 | 4.30 | 3.44 | 3.05 | 2.82 | 2.66 | 2.55 | 2.46 | 2.40 | 2.34 | 2.30 |
| | 23 | 4.28 | 3.42 | 3.03 | 2.80 | 2.64 | 2.53 | 2.44 | 2.37 | 2.32 | 2.27 |
| | 24 | 4.26 | 3.40 | 3.01 | 2.78 | 2.62 | 2.51 | 2.42 | 2.36 | 2.30 | 2.25 |
| | 25 | 4.24 | 3.39 | 2.99 | 2.76 | 2.60 | 2.49 | 2.40 | 2.34 | 2.28 | 2.24 |
| | 26 | 4.23 | 3.37 | 2.98 | 2.74 | 2.59 | 2.47 | 2.39 | 2.32 | 2.27 | 2.22 |
| | 27 | 4.21 | 3.35 | 2.96 | 2.73 | 2.57 | 2.46 | 2.37 | 2.31 | 2.25 | 2.20 |
| | 28 | 4.20 | 3.34 | 2.95 | 2.71 | 2.56 | 2.45 | 2.36 | 2.29 | 2.24 | 2.19 |
| | 29 | 4.18 | 3.33 | 2.93 | 2.70 | 2.55 | 2.43 | 2.35 | 2.28 | 2.22 | 2.18 |
| | 30 | 4.17 | 3.32 | 2.92 | 2.69 | 2.53 | 2.42 | 2.33 | 2.27 | 2.21 | 2.16 |
| | 40 | 4.08 | 3.23 | 2.84 | 2.61 | 2.45 | 2.34 | 2.25 | 2.18 | 2.12 | 2.08 |
| | 60 | 4.00 | 3.15 | 2.76 | 2.53 | 2.37 | 2.25 | 2.17 | 2.10 | 2.04 | 1.99 |
| | 90 | 3.95 | 3.10 | 2.71 | 2.47 | 2.32 | 2.20 | 2.11 | 2.04 | 1.99 | 1.94 |
| | 120 | 3.92 | 3.07 | 2.68 | 2.45 | 2.29 | 2.17 | 2.09 | 2.02 | 1.96 | 1.91 |
| | $\infty$ | 3.84 | 3.00 | 2.60 | 2.37 | 2.21 | 2.10 | 2.01 | 1.94 | 1.88 | 1.83 |

Example: The 5% critical value for numerator $df = 4$ and large denominator $df(\infty)$ is 2.37.

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**TABLE G.3c 1% Critical Values of the *F* Distribution**

| Denominator Degrees of Freedom | Numerator Degrees of Freedom: 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 | 10 |
|---|---|---|---|---|---|---|---|---|---|---|
| 10 | 10.04 | 7.56 | 6.55 | 5.99 | 5.64 | 5.39 | 5.20 | 5.06 | 4.94 | 4.85 |
| 11 | 9.65 | 7.21 | 6.22 | 5.67 | 5.32 | 5.07 | 4.89 | 4.74 | 4.63 | 4.54 |
| 12 | 9.33 | 6.93 | 5.95 | 5.41 | 5.06 | 4.82 | 4.64 | 4.50 | 4.39 | 4.30 |
| 13 | 9.07 | 6.70 | 5.74 | 5.21 | 4.86 | 4.62 | 4.44 | 4.30 | 4.19 | 4.10 |
| 14 | 8.86 | 6.51 | 5.56 | 5.04 | 4.69 | 4.46 | 4.28 | 4.14 | 4.03 | 3.94 |
| 15 | 8.68 | 6.36 | 5.42 | 4.89 | 4.56 | 4.32 | 4.14 | 4.00 | 3.89 | 3.80 |
| 16 | 8.53 | 6.23 | 5.29 | 4.77 | 4.44 | 4.20 | 4.03 | 3.89 | 3.78 | 3.69 |
| 17 | 8.40 | 6.11 | 5.18 | 4.67 | 4.34 | 4.10 | 3.93 | 3.79 | 3.68 | 3.59 |
| 18 | 8.29 | 6.01 | 5.09 | 4.58 | 4.25 | 4.01 | 3.84 | 3.71 | 3.60 | 3.51 |
| 19 | 8.18 | 5.93 | 5.01 | 4.50 | 4.17 | 3.94 | 3.77 | 3.63 | 3.52 | 3.43 |
| 20 | 8.10 | 5.85 | 4.94 | 4.43 | 4.10 | 3.87 | 3.70 | 3.56 | 3.46 | 3.37 |
| 21 | 8.02 | 5.78 | 4.87 | 4.37 | 4.04 | 3.81 | 3.64 | 3.51 | 3.40 | 3.31 |
| 22 | 7.95 | 5.72 | 4.82 | 4.31 | 3.99 | 3.76 | 3.59 | 3.45 | 3.35 | 3.26 |
| 23 | 7.88 | 5.66 | 4.76 | 4.26 | 3.94 | 3.71 | 3.54 | 3.41 | 3.30 | 3.21 |
| 24 | 7.82 | 5.61 | 4.72 | 4.22 | 3.90 | 3.67 | 3.50 | 3.36 | 3.26 | 3.17 |
| 25 | 7.77 | 5.57 | 4.68 | 4.18 | 3.85 | 3.63 | 3.46 | 3.32 | 3.22 | 3.13 |
| 26 | 7.72 | 5.53 | 4.64 | 4.14 | 3.82 | 3.59 | 3.42 | 3.29 | 3.18 | 3.09 |
| 27 | 7.68 | 5.49 | 4.60 | 4.11 | 3.78 | 3.56 | 3.39 | 3.26 | 3.15 | 3.06 |
| 28 | 7.64 | 5.45 | 4.57 | 4.07 | 3.75 | 3.53 | 3.36 | 3.23 | 3.12 | 3.03 |
| 29 | 7.60 | 5.42 | 4.54 | 4.04 | 3.73 | 3.50 | 3.33 | 3.20 | 3.09 | 3.00 |
| 30 | 7.56 | 5.39 | 4.51 | 4.02 | 3.70 | 3.47 | 3.30 | 3.17 | 3.07 | 2.98 |
| 40 | 7.31 | 5.18 | 4.31 | 3.83 | 3.51 | 3.29 | 3.12 | 2.99 | 2.89 | 2.80 |
| 60 | 7.08 | 4.98 | 4.13 | 3.65 | 3.34 | 3.12 | 2.95 | 2.82 | 2.72 | 2.63 |
| 90 | 6.93 | 4.85 | 4.01 | 3.54 | 3.23 | 3.01 | 2.84 | 2.72 | 2.61 | 2.52 |
| 120 | 6.85 | 4.79 | 3.95 | 3.48 | 3.17 | 2.96 | 2.79 | 2.66 | 2.56 | 2.47 |
| ∞ | 6.63 | 4.61 | 3.78 | 3.32 | 3.02 | 2.80 | 2.64 | 2.51 | 2.41 | 2.32 |

Example: The 1% critical value for numerator $df = 3$ and denominator $df = 60$ is 4.13.

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