

# How to Determine Why You Can't Create a Confidence Interval Using the F Distribution

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This discussion addresses a common query in inferential statistics: whether the F distribution can be utilized to construct a confidence interval. While the F distribution is not employed to determine a confidence interval for a single population mean--a task typically reserved for the Z or T distributions--it is absolutely essential for calculating confidence intervals related to the ratio of two population variances. The initial assertion that one cannot create a confidence interval using the F distribution is misleading; it depends entirely on the parameter being estimated. The F distribution is fundamentally designed to compare the dispersion, or **variance**, between two independent samples to ascertain if they likely originate from populations with equal variance.

## Understanding the F Distribution in Comparative Statistics

The F distribution, also known as the Snedecor's F distribution or the Fisher-Snedecor distribution, is a continuous probability distribution that arises frequently as the null distribution of a test statistic in the analysis of variance (ANOVA) and, critically, in the comparison of two population variances. Unlike the standard normal distribution or the t-distribution, the F distribution is uniquely defined by two separate parameters: the numerator degrees of freedom ( $\nu_1$ ) and the denominator degrees of freedom ( $\nu_2$ ). These parameters are crucial as they define the specific shape of the distribution, which is always positive and skewed right.

The primary role of the F distribution in hypothesis testing is to evaluate the ratio of two independent chi-squared variables, each divided by its respective degrees of freedom. When applied to comparing variances, this ratio provides a standardized measure of how much the sample variances deviate from each other. If the ratio of the true population variances is one, the ratio of the sample variances should be close to one, indicating homogeneity. The further this ratio is from unity, the stronger the evidence that the underlying **population variances** are unequal.

## Estimating the Ratio of Two Population Variances

When conducting comparative studies, researchers often need to determine if two distinct groups exhibit similar levels of variability. To formalize this comparison, we calculate the true population variance ratio, denoted as  $\sigma_1 / \sigma_2$ , where  $\sigma_1$  represents the variance of population 1 and  $\sigma_2$  represents the variance of population 2. This ratio is the parameter of interest when utilizing the F distribution for interval estimation.

Since the true population variances are almost always unknown, we rely on empirical data. To estimate this ratio, we draw an independent random sample from each population and compute the sample variance ratio:  $s_1^2 / s_2^2$ . Here,  $s_1^2$  and  $s_2^2$  are the calculated sample variances corresponding to sample 1 and sample 2, respectively. The quality of this estimate hinges on the adherence to specific statistical assumptions.

## Critical Assumptions for Valid F-Intervals

For the confidence interval derived from the F distribution to be statistically valid, several stringent assumptions must be met regarding the data collection and underlying populations. Failure to meet these assumptions can significantly compromise the reliability of the resulting interval. These prerequisites include:

The samples must be drawn **independently** from each of the two populations.

The sample variances, **s<sub>12</sub>** and **s<sub>22</sub>**, must be computed from independent samples of size **n<sub>1</sub>** and **n<sub>2</sub>**.

Crucially, both underlying populations from which the samples are drawn must follow a **normal distribution**. The F test is notoriously sensitive to violations of this normality assumption, particularly when sample sizes are small.

## Deriving the Confidence Interval for the Variance Ratio

The procedure for constructing a confidence interval for the ratio of population variances utilizes the observed ratio of sample variances, **s<sub>12</sub> / s<sub>22</sub>**, adjusted by the critical values obtained from the F distribution table. The general form of the **(1-α)100% confidence interval** for **σ<sub>21</sub> / σ<sub>22</sub>** is defined by the following inequality:

$$(s_{12} / s_{22}) * F_{n_1-1, n_2-1, \alpha/2} \leq \sigma_{21} / \sigma_{22} \leq (s_{12} / s_{22}) * F_{n_2-1, n_1-1, \alpha/2}$$

In this formula, **F<sub>n<sub>2</sub>-1, n<sub>1</sub>-1, α/2</sub>** and **F<sub>n<sub>1</sub>-1, n<sub>2</sub>-1, α/2</sub>** represent the critical values derived from the F distribution. Note the careful inversion of the degrees of freedom (numerator and denominator) and the use of the two-tailed significance level, **α/2**. The critical values are determined by the chosen level of confidence (1-α), which dictates the probability that the true variance ratio falls within the calculated interval.

## Case Study Setup: Defining Parameters for Calculation

To provide a clear, practical demonstration of how to compute this confidence interval, we will use a consistent set of sample data and a defined significance level. We will explore three methods of calculation: manual derivation, application using Microsoft Excel, and scripting in the statistical software R. The following parameters will be used across all examples:

**α** (The significance level) = 0.05.

**n<sub>1</sub>** (Sample size of Population 1) = 16.

**n<sub>2</sub>** (Sample size of Population 2) = 11.

**s<sub>12</sub>** (Sample variance of Population 1) = 28.2.

**s<sub>22</sub>** (Sample variance of Population 2) = 19.3.

## Creating a Confidence Interval By Hand

### Method 1: Calculating the Confidence Interval Manually

The manual calculation of the confidence interval requires plugging the known sample data and the necessary critical values into the defined formula. The first step is calculating the degrees of freedom for the numerator and denominator for the F statistics. For our specific case, the degrees of freedom are  $df1 = n1 - 1 = 15$  and  $df2 = n2 - 1 = 10$ . Since  $\alpha = 0.05$ , we look up the critical values corresponding to  $\alpha/2 = 0.025$ .

We need two critical values from the F distribution table. The F distribution is asymmetrical, meaning we need separate critical values for the lower and upper bounds. We use the F table corresponding to the 0.025 significance level.

The required critical values are:

The upper critical value for the upper bound:  $F_{n2-1, n1-1, \alpha/2} = F_{10, 15, 0.025} = 3.0602$ .

The lower critical value for the lower bound:  $F_{n1-1, n2-1, \alpha/2}$ . This value is calculated using the reciprocal property of the F distribution:  $1 / F_{15, 10, 0.025} = 1 / 3.5217 = 0.2839$ .

DF2	DF1 $\alpha = 0.025$																		
	1	2	3	4	5	6	7	8	9	10	12	15	20	24	30	40	60	120	Inf
1	647.79	799.5	864.16	899.58	921.85	937.11	948.22	956.66	963.28	968.63	976.71	984.87	993.1	997.25	1001.4	1005.6	1009.8	1014	1018.3
2	38.506	39	39.166	39.248	39.298	39.332	39.355	39.373	39.387	39.398	39.415	39.431	39.448	39.456	39.465	39.473	39.481	39.49	39.498
3	17.443	16.044	15.439	15.101	14.885	14.735	14.624	14.54	14.473	14.419	14.337	14.253	14.124	14.081	14.037	13.992	13.947	13.902	
4	12.218	10.649	9.9792	9.6045	9.3645	9.1973	9.0741	8.9796	8.9047	8.8439	8.7512	8.6565	8.5599	8.5109	8.461	8.411	8.36	8.309	8.257
5	10.007	8.4336	7.7636	7.3879	7.1464	6.9777	6.8531	6.7572	6.6811	6.6192	6.5245	6.4277	6.3286	6.278	6.227	6.175	6.123	6.069	6.015
6	8.8131	7.2599	6.5988	6.2272	5.9876	5.8198	5.6955	5.5996	5.5234	5.4613	5.3662	5.2687	5.1684	5.1172	5.065	5.012	4.959	4.904	4.849
7	8.0727	6.5415	5.8898	5.5226	5.2852	5.1186	4.9949	4.8993	4.8232	4.7611	4.6658	4.5678	4.4667	4.415	4.362	4.309	4.254	4.199	4.142
8	7.5709	6.0595	5.416	5.0526	4.8173	4.6517	4.5286	4.4333	4.3572	4.2951	4.1997	4.1012	3.9995	3.9472	3.894	3.84	3.784	3.728	3.67
9	7.2093	5.7147	5.0781	4.7181	4.4844	4.3197	4.197	4.102	4.026	3.9639	3.8682	3.7694	3.6669	3.6142	3.56	3.505	3.449	3.392	3.333
10	6.9367	5.4564	4.8256	4.4683	4.2361	4.0721	3.9498	3.8549	3.779	3.7168	3.6209	3.5217	3.4185	3.3654	3.311	3.255	3.198	3.14	3.08
11	6.7241	5.2559	4.63	4.2751	4.044	3.8807	3.7586	3.6638	3.5879	3.5257	3.4296	3.3299	3.2261	3.1725	3.118	3.061	3.004	2.944	2.883
12	6.5538	5.0959	4.4742	4.1212	3.8911	3.7283	3.6065	3.5118	3.4358	3.3736	3.2773	3.1772	3.0728	3.0187	2.963	2.906	2.848	2.787	2.725
13	6.4143	4.9653	4.3472	3.9959	3.7667	3.6043	3.4827	3.388	3.312	3.2497	3.1532	3.0527	2.9477	2.8932	2.837	2.78	2.72	2.659	2.595
14	6.2979	4.8567	4.2417	3.8919	3.6634	3.5014	3.3799	3.2853	3.2093	3.1469	3.0502	2.9493	2.8437	2.7888	2.732	2.674	2.614	2.552	2.487
15	6.1995	4.765	4.1528	3.8043	3.5764	3.4147	3.2934	3.1987	3.1227	3.0602	2.9633	2.8621	2.7559	2.7006	2.644	2.585	2.524	2.461	2.395
16	6.1151	4.6867	4.0768	3.7294	3.5021	3.3406	3.2194	3.1248	3.0488	2.9862	2.889	2.7875	2.6808	2.6252	2.568	2.509	2.447	2.383	2.316
17	6.042	4.6189	4.0112	3.6648	3.4379	3.2767	3.1556	3.061	2.9849	2.9222	2.8249	2.723	2.6158	2.5598	2.502	2.442	2.38	2.315	2.247
18	5.9781	4.5597	3.9539	3.6083	3.382	3.2209	3.0999	3.0053	2.9291	2.8664	2.7689	2.6667	2.559	2.5027	2.445	2.384	2.321	2.256	2.187
19	5.9216	4.5075	3.9034	3.5587	3.3327	3.1718	3.0509	2.9563	2.8801	2.8172	2.7196	2.6171	2.5089	2.4523	2.394	2.333	2.27	2.203	2.133
20	5.8715	4.4613	3.8587	3.5147	3.2891	3.1283	3.0074	2.9128	2.8365	2.7737	2.6758	2.5731	2.4645	2.4076	2.349	2.287	2.223	2.156	2.085
21	5.8266	4.4199	3.8188	3.4754	3.2501	3.0895	2.9686	2.874	2.7977	2.7348	2.6368	2.5338	2.4247	2.3675	2.308	2.246	2.182	2.114	2.042
22	5.7863	4.3828	3.7829	3.4401	3.2151	3.0546	2.9338	2.8392	2.7628	2.6998	2.6017	2.4984	2.389	2.3315	2.272	2.21	2.145	2.076	2.003
23	5.7498	4.3492	3.7505	3.4083	3.1835	3.0232	2.9023	2.8077	2.7313	2.6682	2.5699	2.4665	2.3567	2.2989	2.239	2.176	2.111	2.041	1.968
24	5.7166	4.3187	3.7211	3.3794	3.1548	2.9946	2.8738	2.7791	2.7027	2.6396	2.5411	2.4374	2.3273	2.2693	2.209	2.146	2.08	2.01	1.935
25	5.6864	4.2909	3.6943	3.353	3.1287	2.9685	2.8478	2.7531	2.6766	2.6135	2.5149	2.411	2.3005	2.2422	2.182	2.118	2.052	1.981	1.906
26	5.6586	4.2655	3.6697	3.3289	3.1048	2.9447	2.824	2.7293	2.6528	2.5896	2.4908	2.3867	2.2759	2.2174	2.157	2.093	2.026	1.954	1.878
27	5.6331	4.2421	3.6472	3.3067	3.0828	2.9228	2.8021	2.7074	2.6309	2.5676	2.4688	2.3644	2.2533	2.1946	2.133	2.069	2.002	1.93	1.853
28	5.6096	4.2205	3.6264	3.2863	3.0626	2.9027	2.782	2.6872	2.6106	2.5473	2.4484	2.3438	2.2324	2.1735	2.112	2.048	1.98	1.907	1.829
29	5.5878	4.2006	3.6072	3.2674	3.0438	2.884	2.7633	2.6686	2.5919	2.5286	2.4295	2.3248	2.2131	2.154	2.092	2.028	1.959	1.886	1.807
30	5.5675	4.1821	3.5894	3.2499	3.0265	2.8667	2.746	2.6513	2.5746	2.5112	2.412	2.3072	2.1952	2.1359	2.074	2.009	1.94	1.866	1.787
40	5.4239	4.051	3.4633	3.1261	2.9037	2.7444	2.6238	2.5289	2.4519	2.3882	2.2882	2.1819	2.0677	2.0069	1.943	1.875	1.803	1.724	1.637
60	5.2856	3.9253	3.3425	3.0077	2.7863	2.6274	2.5068	2.4117	2.3344	2.2702	2.1692	2.0613	1.9445	1.8817	1.815	1.744	1.667	1.581	1.482
120	5.1523	3.8046	3.2269	2.8943	2.674	2.5154	2.3948	2.2994	2.2217	2.157	2.0548	1.945	1.8249	1.7597	1.69	1.614	1.53	1.433	1.31
Inf	5.0239	3.6889	3.1161	2.7858	2.5665	2.4082	2.2875	2.1918	2.1136	2.0483	1.9447	1.8326	1.7085	1.6402	1.566	1.484	1.388	1.268	1

With both the sample statistics and the critical values determined, we substitute these numbers

into the full confidence interval formula. The calculated ratio of sample variances is  $28.2 / 19.3 \approx 1.4611$ . The formula application proceeds as follows:

$$(s_{12} / s_{22}) * F_{n_1-1, n_2-1, \alpha/2} \leq \sigma_{21} / \sigma_{22} \leq (s_{12} / s_{22}) * F_{n_2-1, n_1-1, \alpha/2}$$

$$(28.2 / 19.3) * (0.2839) \leq \sigma_{21} / \sigma_{22} \leq (28.2 / 19.3) * (3.0602)$$

$$0.4148 \leq \sigma_{21} / \sigma_{22} \leq 4.4714$$

The resulting 95% confidence interval for the ratio of the true population variances is determined to be **(0.4148, 4.4714)**. This implies that we are 95% confident that the true ratio of the variability between the two populations falls within this specified range.

## Creating a Confidence Interval Using Excel

### Method 2: Utilizing Microsoft Excel for Calculation

Microsoft Excel offers built-in functions that streamline the process of finding the critical F values and calculating the confidence interval bounds, eliminating the need to manually consult statistical tables. This method provides a rapid and highly precise calculation of the interval.

To calculate the lower and upper bounds of the 95% confidence interval in Excel, one must use the appropriate F-inverse functions combined with the sample ratio. The image below displays the required inputs for the sample sizes and variances, and the resulting confidence interval bounds calculated using Excel's statistical functions. The formulas used rely on the two-tailed inverse F distribution function, which incorporates the specified significance level,  $\alpha$ , and the appropriate degrees of freedom for the numerator and denominator.

	A	B	C	D	E	F	G	H	I
1	$\alpha$	0.05		Lower Bound	0.414899	$= (1/F.INV.RT(B1/2, B2-1, B3-1)) * (B4/B5)$			
2	$n_1$	16		Upper Bound	4.471376	$= F.INV.RT(B1/2, B3-1, B2-1) * (B4/B5)$			
3	$n_2$	11							
4	$s_1^2$	28.2							
5	$s_2^2$	19.3							

As demonstrated by the Excel output, the 95% confidence interval for the ratio of the **population variances** is calculated as **(0.4148, 4.4714)**. This result is consistent with the value obtained through the manual, step-by-step calculation, confirming the accuracy of the process across different computational methods.

## Creating a Confidence Interval Using R

### Method 3: Implementation Using the R Statistical Software

For large-scale data analysis and automated statistical reporting, the R programming language provides robust functions for statistical distributions. Calculating the confidence interval for the variance ratio in R involves defining the input parameters and using the built-in quantile function for the F distribution, denoted as `qf()`. This function efficiently returns the critical F values necessary for the calculation.

The following R script defines the significance level, sample sizes, and variances. It then calculates the necessary critical F values, ensuring that the appropriate degrees of freedom are used in the correct order for the upper and lower bounds. Finally, it applies the formula to determine and output the confidence interval bounds.

```
#define significance level, sample sizes, and sample variances
```

```
alpha <- .05
```

```
n1 <- 16
```

```
n2 <- 11
```

```
var1 <- 28.2
```

```
var2 <- 19.3
```

```
#define F critical values
```

```
upper_crit <- 1/qf(alpha/2, n1-1, n2-1)
```

```
lower_crit <- qf(alpha/2, n2-1, n1-1)
```

```
#find confidence interval
```

```
lower_bound <- (var1/var2) * lower_crit
```

```
upper_bound <- (var1/var2) * upper_crit
```

```
#output confidence interval
```

```
paste0("(", lower_bound, ", ", upper_bound, ")")
```

```
# "(0.414899337980266, 4.47137571035219)"
```

The R output confirms the precise numerical calculation of the 95% confidence interval for the variance ratio, yielding the interval **(0.4148, 4.4714)**. This final result is highly consistent across all three presented methodologies--manual calculation, Excel, and R--thereby validating the robust application of the F distribution methodology for estimating the ratio of two independent population variances.

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