# qc — Quality control charts

## Syntax

**Draw a c chart**

\[
cchart \ \text{defect}\_\text{var} \ \text{unit}\_\text{var} \ [, \ cchart\_\text{options}]\]

**Draw a p (fraction-defective) chart**

\[
pchart \ \text{reject}\_\text{var} \ \text{unit}\_\text{var} \ \text{ssize}\_\text{var} \ [, \ pchart\_\text{options}]\]

**Draw an R (range or dispersion) chart**

\[
rchart \ \text{varlist} \ [\ if] \ [\ in] \ [, \ rchart\_\text{options}]\]

**Draw an \(\bar{X}\) (control line) chart**

\[
xchart \ \text{varlist} \ [\ if] \ [\ in] \ [, \ xchart\_\text{options}]\]

**Draw vertically aligned \(\bar{X}\) and R charts**

\[
shewhart \ \text{varlist} \ [\ if] \ [\ in] \ [, \ shewhart\_\text{options}]\]

### cchart_options

<table>
<thead>
<tr>
<th>Option</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Main</strong></td>
<td></td>
</tr>
<tr>
<td><strong>nograph</strong></td>
<td>suppress graph</td>
</tr>
<tr>
<td><strong>Plot</strong></td>
<td></td>
</tr>
<tr>
<td><strong>connect_options</strong></td>
<td>affect rendition of the plotted points</td>
</tr>
<tr>
<td><strong>marker_options</strong></td>
<td>change look of markers (color, size, etc.)</td>
</tr>
<tr>
<td><strong>marker_label_options</strong></td>
<td>add marker labels; change look or position</td>
</tr>
<tr>
<td><strong>Control limits</strong></td>
<td></td>
</tr>
<tr>
<td><strong>clopts(cline_options)</strong></td>
<td>affect rendition of the control limits</td>
</tr>
<tr>
<td><strong>Add plots</strong></td>
<td></td>
</tr>
<tr>
<td><strong>addplot(plot)</strong></td>
<td>add other plots to the generated graph</td>
</tr>
<tr>
<td><strong>Y axis, X axis, Titles, Legend, Overall</strong></td>
<td>(\text{twoway_options}) any options other than \text{by()} documented in [G-3] \text{twoway_options}\</td>
</tr>
</tbody>
</table>
### pchart_options

**Main**

- **stabilized**
- **nograph**
- **generate**(newvar \( f \) newvar \(_{lcl} \) newvar \(_{ucl} \))

  - stabilize the p chart when sample sizes are unequal
  - suppress graph
  - store the fractions of defective elements and the lower and upper control limits

**Plot**

- **connect_options**
- **marker_options**
- **marker_label_options**

  - affect rendition of the plotted points
  - change look of markers (color, size, etc.)
  - add marker labels; change look or position

**Control limits**

- **clopts**(cline_options)

  - affect rendition of the control limits

**Add plots**

- **addplot**(plot)

  - add other plots to the generated graph

**Y axis, X axis, Titles, Legend, Overall**

- **twoway_options**

  - any options other than by() documented in [G-3] \textit{twoway_options}

### rchart_options

**Main**

- **std(#)**
- **nograph**

  - user-specified standard deviation
  - suppress graph

**Plot**

- **connect_options**
- **marker_options**
- **marker_label_options**

  - affect rendition of the plotted points
  - change look of markers (color, size, etc.)
  - add marker labels; change look or position

**Control limits**

- **clopts**(cline_options)

  - affect rendition of the control limits

**Add plots**

- **addplot**(plot)

  - add other plots to the generated graph

**Y axis, X axis, Titles, Legend, Overall**

- **twoway_options**

  - any options other than by() documented in [G-3] \textit{twoway_options}
**xchart_options**  

**Main**

<table>
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<tbody>
<tr>
<td><code>std(#)</code></td>
<td>user-specified standard deviation</td>
</tr>
<tr>
<td><code>mean(#)</code></td>
<td>user-specified mean</td>
</tr>
<tr>
<td><code>lower(#)</code> <code>upper(#)</code></td>
<td>lower and upper limits of the X-bar limits</td>
</tr>
<tr>
<td><code>nograph</code></td>
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</tbody>
</table>

**Plot**

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</tr>
</tbody>
</table>

**shewhart_options**  

**Main**

<table>
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<th>Description</th>
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</thead>
<tbody>
<tr>
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<tr>
<td><code>mean(#)</code></td>
<td>user-specified mean</td>
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<tbody>
<tr>
<td><code>combine_options</code></td>
<td>any options documented in [G-2] graph combine</td>
</tr>
</tbody>
</table>

**Menu**

<table>
<thead>
<tr>
<th>Command</th>
<th>Statistics &gt; Other &gt; Quality control &gt;</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td><code>cchart</code></td>
<td>C chart</td>
<td></td>
</tr>
<tr>
<td><code>pchart</code></td>
<td>P chart</td>
<td></td>
</tr>
<tr>
<td><code>rchart</code></td>
<td>R chart</td>
<td></td>
</tr>
</tbody>
</table>
**Description**

These commands provide standard quality-control charts. `cchart` draws a c chart; `pchart`, a p (fraction-defective) chart; `rchart`, an R (range or dispersion) chart; `xchart`, an $\bar{X}$ (control line) chart; and `shewhart`, vertically aligned $\bar{X}$ and R charts.

**Options**

---

**Main**

- `stabilized` stabilizes the p chart when sample sizes are unequal.
- `std(#)` specifies the standard deviation of the process. The R chart is calculated (based on the range) if this option is not specified.
- `mean(#)` specifies the grand mean, which is calculated if not specified.
- `lower(#)` and `upper(#)` must be specified together or not at all. They specify the lower and upper limits of the $\bar{X}$ chart. Calculations based on the mean and standard deviation (whether specified by option or calculated) are used otherwise.
- `nograph` suppresses the graph.
- `generate(newvar_f newvar_lcl newvar_ucl)` stores the plotted values in the p chart. `newvar_f` will contain the fractions of defective elements; `newvar_lcl` and `newvar_ucl` will contain the lower and upper control limits, respectively.

---

**Plot**

- `connect_options` affect whether lines connect the plotted points and the rendition of those lines; see [G-3] `connect_options`.
- `marker_options` affect the rendition of markers drawn at the plotted points, including their shape, size, color, and outline; see [G-3] `marker_options`.
- `marker_label_options` specify if and how the markers are to be labeled; see [G-3] `marker_label_options`.

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**Control limits**

- `clopts(cline_options)` affects the rendition of the control limits; see [G-3] `cline_options`.

---

**Add plots**

- `addplot(plot)` provides a way to add other plots to the generated graph. See [G-3] `addplot_option`.

---

**Y axis, X axis, Titles, Legend, Overall**

- `twoway_options` are any of the options documented in [G-3] `twoway_options`, excluding by(). These include options for titling the graph (see [G-3] `title_options`) and for saving the graph to disk (see [G-3] `saving_option`).
combine_options (shewhart only) are any of the options documented in [G-2] graph combine. These include options for titling the graph (see [G-3] title_options) and for saving the graph to disk (see [G-3] saving_option).

Remarks and examples

Control charts may be used to define the goal of a repetitive process, to control that process, and to determine if the goal has been achieved. Walter A. Shewhart of Bell Telephone Laboratories devised the first control chart in 1924. In 1931, Shewhart published *Economic Control of Quality of Manufactured Product*. According to Burr, “Few fields of knowledge have ever been so completely explored and charted in the first exposition” (1976, 29). Shewhart states that “a phenomenon will be said to be controlled when, through the use of past experience, we can predict, at least within limits, how the phenomenon may be expected to vary in the future. Here it is understood that prediction within limits means that we can state, at least approximately, the probability that the observed phenomenon will fall within given limits” (1931, 6).

For more information on quality-control charts, see Burr (1976), Duncan (1986), Harris (1999), or Ryan (2000).

Example 1: cchart

cchart graphs a c chart showing the number of nonconformities in a unit, where defect_var records the number of defects in each inspection unit and unit_var records the unit number. The unit numbers need not be in order. For instance, consider the following example dataset from Ryan (2000, 156):

```
. use http://www.stata-press.com/data/r13/ncu
. describe
Contains data from http://www.stata-press.com/data/r13/ncu.dta
    obs:   30
    vars:   2  31 Mar 2013 03:56
    size:   240

     storage  display   value
variable name type    format label          variable label
--- ------------------ --------- -----------------------------
day     float  %9.0g    Days in April
 defects  float  %9.0g  Numbers of Nonconforming Units
```

Sorted by:
```
. list in 1/5

<table>
<thead>
<tr>
<th>day</th>
<th>defects</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3</td>
<td>11</td>
</tr>
<tr>
<td>4</td>
<td>13</td>
</tr>
<tr>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>
```
The expected number of defects is 10.6, with lower and upper control limits of 0.8327 and 20.37, respectively. No units are out of control.

Example 2: pchart

pchart graphs a p chart, which shows the fraction of nonconforming items in a subgroup, where reject_var records the number rejected in each inspection unit, unit_var records the inspection unit number, and ssize_var records the number inspected in each unit.

Consider the example dataset from Ryan (2000, 156) of the number of nonconforming transistors out of 1,000 inspected each day during the month of April:

```
. use http://www.stata-press.com/data/r13/ncu2
. describe
Contains data from http://www.stata-press.com/data/r13/ncu2.dta
    obs: 30                              31 Mar 2013 14:13
    vars: 3                             size: 360
storage   display     value
variable name  type    format   label       variable label
  day          float    %9.0g   label       Days in April
 reject       float    %9.0g   label       Numbers of Nonconforming Units
 ssize         float    %9.0g   label       Sample size
Sorted by:
```
All the points are within the control limits, which are 0.0009 for the lower limit and 0.0203 for the upper limit.

Here the sample sizes are fixed at 1,000, so the ssize variable contains 1,000 for each observation. Sample sizes need not be fixed, however. Say that our data were slightly different:

```
. use http://www.stata-press.com/data/r13/ncu3
. list in 1/5
```

<table>
<thead>
<tr>
<th>day</th>
<th>rejects</th>
<th>ssize</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>1</td>
<td>7</td>
</tr>
<tr>
<td>2.</td>
<td>2</td>
<td>5</td>
</tr>
<tr>
<td>3.</td>
<td>3</td>
<td>11</td>
</tr>
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</tr>
<tr>
<td>5.</td>
<td>5</td>
<td>9</td>
</tr>
</tbody>
</table>

0 units are out of control
. pchart rejects day ssize

Here the control limits are, like the sample size, no longer constant. The `stabilize` option will stabilize the control chart:

. pchart rejects day ssize, stabilize
Example 3: `rchart`

`rchart` displays an R chart showing the range for repeated measurements at various times. Variables within observations record measurements. Observations represent different samples.

For instance, say that we take five samples of 5 observations each. In our first sample, our measurements are 10, 11, 10, 11, and 12. The data are

```
. list

<table>
<thead>
<tr>
<th></th>
<th>m1</th>
<th>m2</th>
<th>m3</th>
<th>m4</th>
<th>m5</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>11</td>
<td>12</td>
</tr>
<tr>
<td>2</td>
<td>12</td>
<td>10</td>
<td>9</td>
<td>10</td>
<td>9</td>
</tr>
<tr>
<td>3</td>
<td>10</td>
<td>11</td>
<td>10</td>
<td>12</td>
<td>10</td>
</tr>
<tr>
<td>4</td>
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<td>9</td>
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<td>5</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>12</td>
<td>13</td>
</tr>
</tbody>
</table>
```

`. rchart m1-m5, connect(l)`

The expected range in each sample is 2 with lower and upper control limits of 0 and 4.23, respectively. If we know that the process standard deviation is 0.3, we could specify
Example 4: xchart

xchart graphs an $\bar{X}$ chart for repeated measurements at various times. Variables within observations record measurements, and observations represent different samples. Using the same data as in the previous example, we type

```
.xchart m1-m5, connect(l)
```

The average measurement in the sample is 10.64, and the lower and upper control limits are 9.486 and 11.794, respectively. Suppose that we knew from prior information that the mean of the process is 11. Then we would type
. xchart m1-m5, connect(l) mean(11)

If we also know that the standard deviation of the process is 0.3, we could type

. xchart m1-m5, connect(l) mean(11) std(.3)

Finally, `xchart` allows us to specify our own control limits:
Walter Andrew Shewhart (1891–1967) was born in Illinois and educated as a physicist, with degrees from the Universities of Illinois and California. After a brief period teaching physics, he worked for the Western Electric Company and (from 1925) the Bell Telephone Laboratories. His name is most associated with control charts used in quality controls, but his many other interests ranged generally from quality assurance to the philosophy of science.

Example 5: shewhart

shewhart displays a vertically aligned $\bar{X}$ and R chart in the same image. To produce the best-looking combined image possible, you will want to use the xchart and rchart commands separately and then combine the graphs. shewhart, however, is more convenient.

Using the same data as previously, but realizing that the standard deviation should have been 0.4, we type
Stored results

cchart stores the following in r():

Scalars
- r(cbar)  expected number of nonconformities
- r(lcl_c) lower control limit
- r(ucl_c) upper control limit
- r(N)    number of observations
- r(out_c) number of units out of control
- r(below_c) number of units below the lower limit
- r(above_c) number of units above the upper limit

pchart stores the following in r():

Scalars
- r(pbar) average fraction of nonconformities
- r(lcl_p) lower control limit
- r(ucl_p) upper control limit
- r(N) number of observations
- r(out_p) number of units out of control
- r(below_p) number of units below the lower limit
- r(above_p) number of units above the upper limit

rchart stores the following in r():

Scalars
- r(central_line) ordinate of the central line
- r(lcl_r) lower control limit
- r(ucl_r) upper control limit
- r(N) number of observations
- r(out_r) number of units out of control
- r(below_r) number of units below the lower limit
- r(above_r) number of units above the upper limit
**xchart** stores the following in \( r() \):

- **Scalars**
  - \( r(xbar) \): grand mean
  - \( r(lcl_x) \): lower control limit
  - \( r(ucl_x) \): upper control limit
  - \( r(N) \): number of observations
  - \( r(out_x) \): number of units out of control
  - \( r(below_x) \): number of units below the lower limit
  - \( r(above_x) \): number of units above the upper limit

**shewhart** stores in \( r() \) the combination of stored results from **xchart** and **rchart**.

## Methods and formulas

For the \( c \) chart, the number of defects per unit, \( C \), is taken to be a value of a random variable having a Poisson distribution. If \( k \) is the number of units available for estimating \( \lambda \), the parameter of the Poisson distribution, and if \( C_i \) is the number of defects in the \( i \)th unit, then \( \lambda \) is estimated by \( \bar{C} = \sum_i C_i/k \). Then

\[
\begin{align*}
\text{central line} &= \bar{C} \\
\text{UCL} &= \bar{C} + 3\sqrt{\bar{C}} \\
\text{LCL} &= \bar{C} - 3\sqrt{\bar{C}}
\end{align*}
\]

Control limits for the \( p \) chart are based on the sampling theory for proportions, using the normal approximation to the binomial. If \( k \) samples are taken, the estimator of \( p \) is given by \( \bar{p} = \frac{\sum_i \hat{p}_i}{k} \), where \( \hat{p}_i = \frac{x_i}{n_i} \), and \( x_i \) is the number of defects in the \( i \)th sample of size \( n_i \). The central line and the control limits are given by

\[
\begin{align*}
\text{central line} &= \bar{p} \\
\text{UCL} &= \bar{p} + 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n_i}} \\
\text{LCL} &= \bar{p} - 3\sqrt{\frac{\bar{p}(1-\bar{p})}{n_i}}
\end{align*}
\]

Control limits for the \( R \) chart are based on the distribution of the range of samples of size \( n \) from a normal population. If the standard deviation of the process, \( \sigma \), is known,

\[
\begin{align*}
\text{central line} &= d_2 \sigma \\
\text{UCL} &= D_2 \sigma \\
\text{LCL} &= D_1 \sigma
\end{align*}
\]

where \( d_2, D_1, \) and \( D_2 \) are functions of the number of observations in the sample and are obtained from the table published in Beyer (1976).

When \( \sigma \) is unknown,

\[
\begin{align*}
\text{central line} &= \bar{R} \\
\text{UCL} &= (D_2/d_2)\bar{R} \\
\text{LCL} &= (D_1/d_2)\bar{R}
\end{align*}
\]

where \( \bar{R} = \frac{\sum_i R_i}{k} \) is the range of the \( k \) sample ranges \( R_i \).
Control limits for the $\bar{X}$ chart are given by

\[
\begin{align*}
\text{central line} &= \bar{x} \\
\text{UCL} &= \bar{x} + \left(\frac{3}{\sqrt{n}}\right)\sigma \\
\text{LCL} &= \bar{x} - \left(\frac{3}{\sqrt{n}}\right)\sigma
\end{align*}
\]

if $\sigma$ is known. If $\sigma$ is unknown,

\[
\begin{align*}
\text{central line} &= \bar{x} \\
\text{UCL} &= \bar{x} + A_2 \overline{R} \\
\text{LCL} &= \bar{x} - A_2 \overline{R}
\end{align*}
\]

where $\overline{R}$ is the average range as defined above and $A_2$ is a function (op. cit.) of the number of observations in the sample.

References


Also see

[R] serrbar — Graph standard error bar chart