Creating plots in R using ggplot2 - part 11: linear regression plot

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Contents

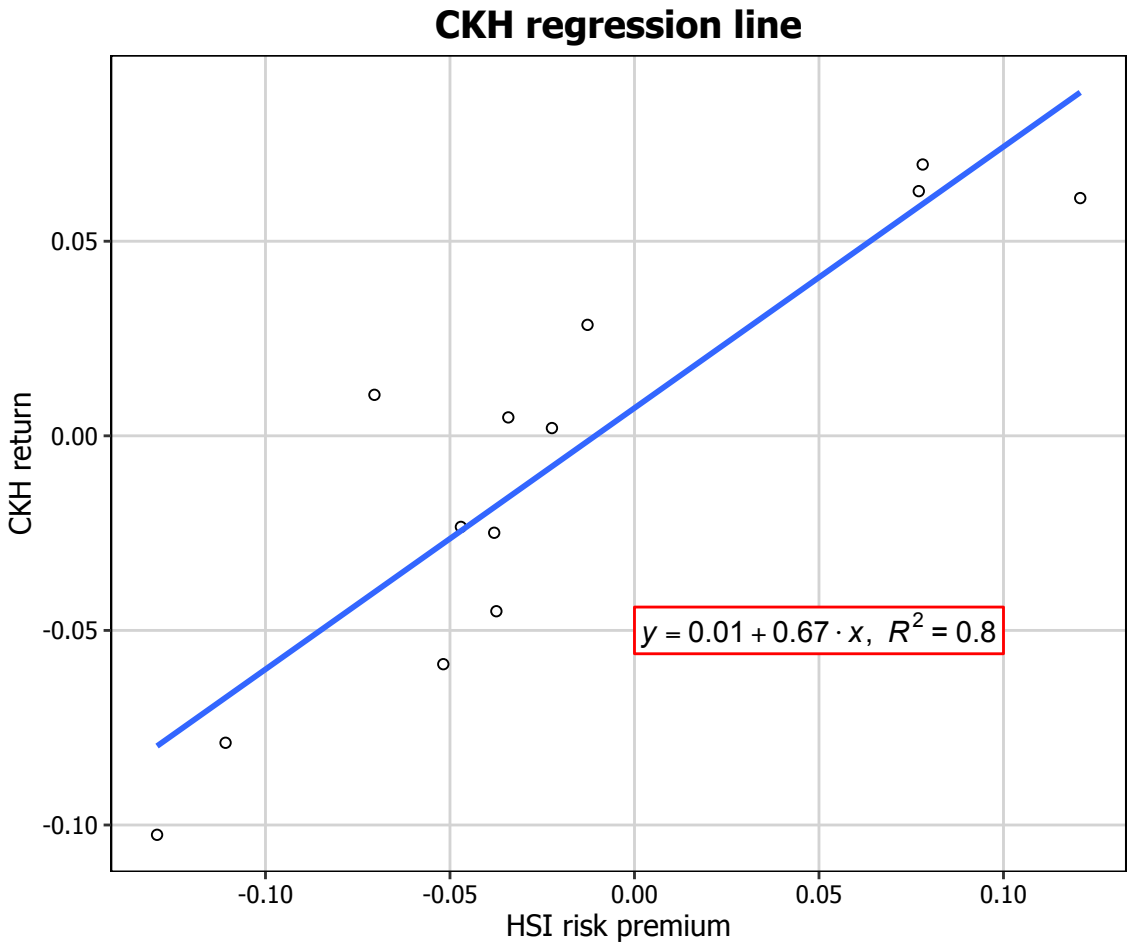
This is the eleventh tutorial in a series on using `ggplot2` I am creating with Mauricio Vargas Sepúlveda. In this tutorial we will demonstrate some of the many options the `ggplot2` package.

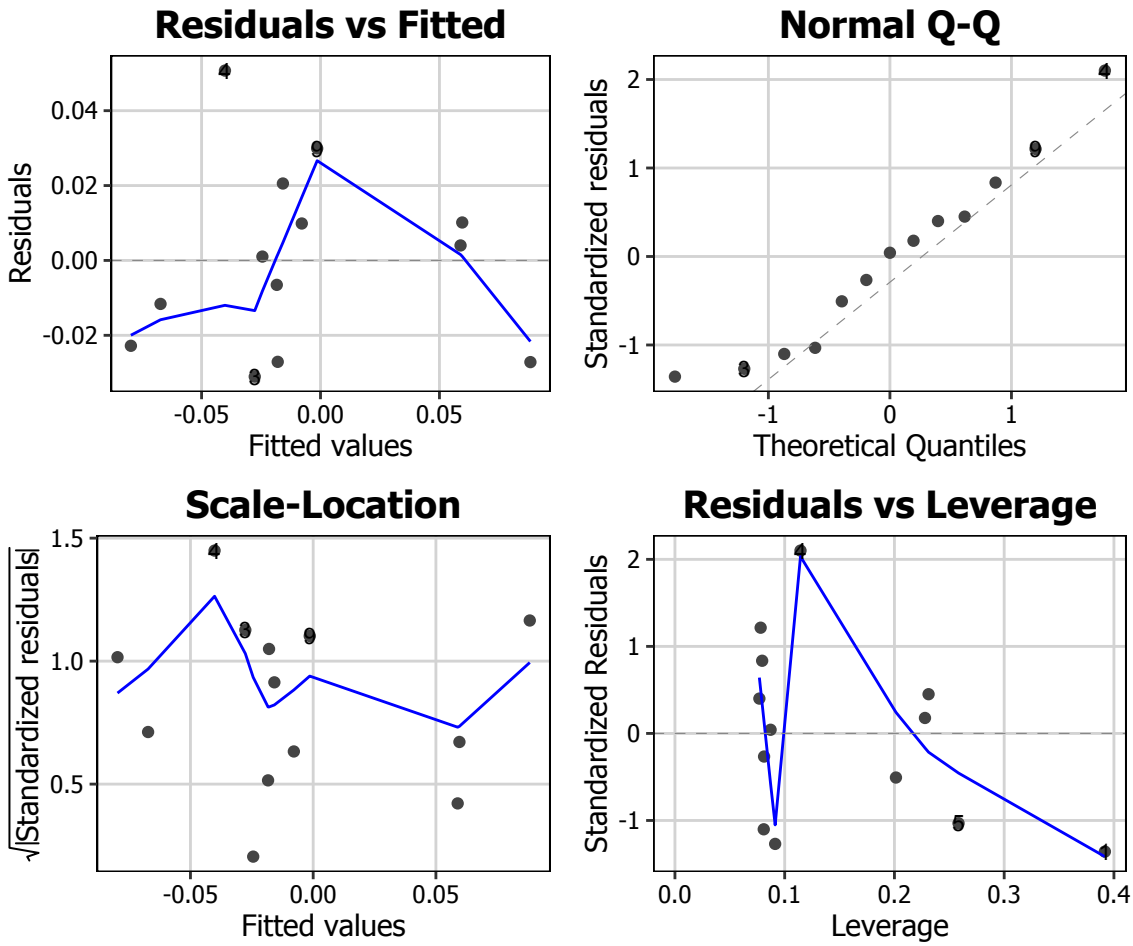
This post will be much more than showing you how to create regression plots. Here we are extracting, cleaning and processing financial data from Quandl.

Before going ahead, we strongly suggest to create a Quandl account in order to obtain an API key that allows you to download data without restrictions. It is even possible to log into Quandl using Github or Linkedin accounts. Quandl's website has complete instruction and they have an API that is 100% R compatible.

The goal is to estimate the CAPM model $R_i = R_f + \beta_i[R_m - R_f] + e_i$ where R_i is the return of an asset, R_f is the risk-free return (e.g. US Treasury Bonds), R_m is the return of the market portfolio (e.g. NYSE) and β_i is a measure of risk relative to the market (e.g. $\beta_i = 1$ means that asset is exactly as risky as the market portfolio). More on the CAPM model can be read here, but in this tutorial we will focus on plotting.

In this tutorial, we will work towards creating the trend line and diagnostics plots below. We will take you from a basic regression plot and explain all the customisations we add to the code step-by-step.


CKH regression line
CKH return
HSI risk premium
0.05
0.00
-0.05
-0.10
-0.10
-0.05
0.00
0.05
0.10
$y = 0.01 + 0.67 \cdot x,\ R^2 = 0.8$



The first thing to do is download and load in the libraries and the data of the monthly price of Hang Seng Index and Cheung Kong Holdings Hong Kong from 2015-03-01 to 2016-04-01.

```
library(ggplot2)
library(ggthemes)
library(grid)
library(ggfortify)
library(Quandl)
Quandl.api_key("XXX")

hsi.df <- Quandl("YAHOO/INDEX_HSI", start_date="2015-03-01", end_date="2016-04-01",
    collapse="monthly", type = "raw")

ckh.df <- Quandl("YAHOO/HK_0001", start_date="2015-03-01",
    end_date="2016-04-01", collapse="monthly", type = "raw")

saveRDS(hsi.df, "hsi.rds"); saveRDS(ckh.df,"ckh.rds")
```

Before calculating return as $R_i = \frac{P_t - P_{t-1}}{P_t}$ we need to order HSI and CKH data by dates and in decreasing order.

```
hsi.df <- readRDS("hsi.rds")
colnames(hsi.df)[7] <- "Adjusted.Close"
hsi.df <- hsi.df[order(as.Date(hsi.df$Date)),]
```

With ordered dates it is possible to obtain the correct return for each month.

```
hsi.Adjusted.Close <- hsi.df$Adjusted.Close
hsi.Return <- diff(hsi.Adjusted.Close)/hsi.Adjusted.Close[-length(hsi.Adjusted.Close)]
hsi.Return <- c(NA,hsi.Return)
hsi.df$Return <- hsi.Return
hsi.df <- na.omit(hsi.df)
hsi.Return <- hsi.df[,c("Date","Return")]

ckh.df <- readRDS("ckh.rds")
colnames(ckh.df)[7] <- "Adjusted.Close"
ckh.df <- ckh.df[order(as.Date(ckh.df$Date)),]
ckh.Adjusted.Close <- ckh.df$Adjusted.Close
ckh.Return <- diff(ckh.Adjusted.Close)/ckh.Adjusted.Close[-length(ckh.Adjusted.Close)]
ckh.Return <- c(NA,ckh.Return)
ckh.df <- na.omit(ckh.df)
ckh.df$Return <- ckh.Return
ckh.Return <- ckh.df[,c("Date","Return")]
```

The returns can be arranged in one data frame before doing plots and regression.

```
hsi.ckh.returns <- merge(hsi.Return, ckh.Return, by='Date')
hsi.ckh.returns <- na.omit(hsi.ckh.returns)
colnames(hsi.ckh.returns) <- c("Date","hsi.Return","ckh.Return")
```

Using Damodaran and Bloomberg data we can work with an estimate of HSI risk premium over risk-free rate.

```
usa.risk.free <- 0.3/100
hsi.risk.premium <- 0.6/100
```

Trend line plot

Basic trend line plot

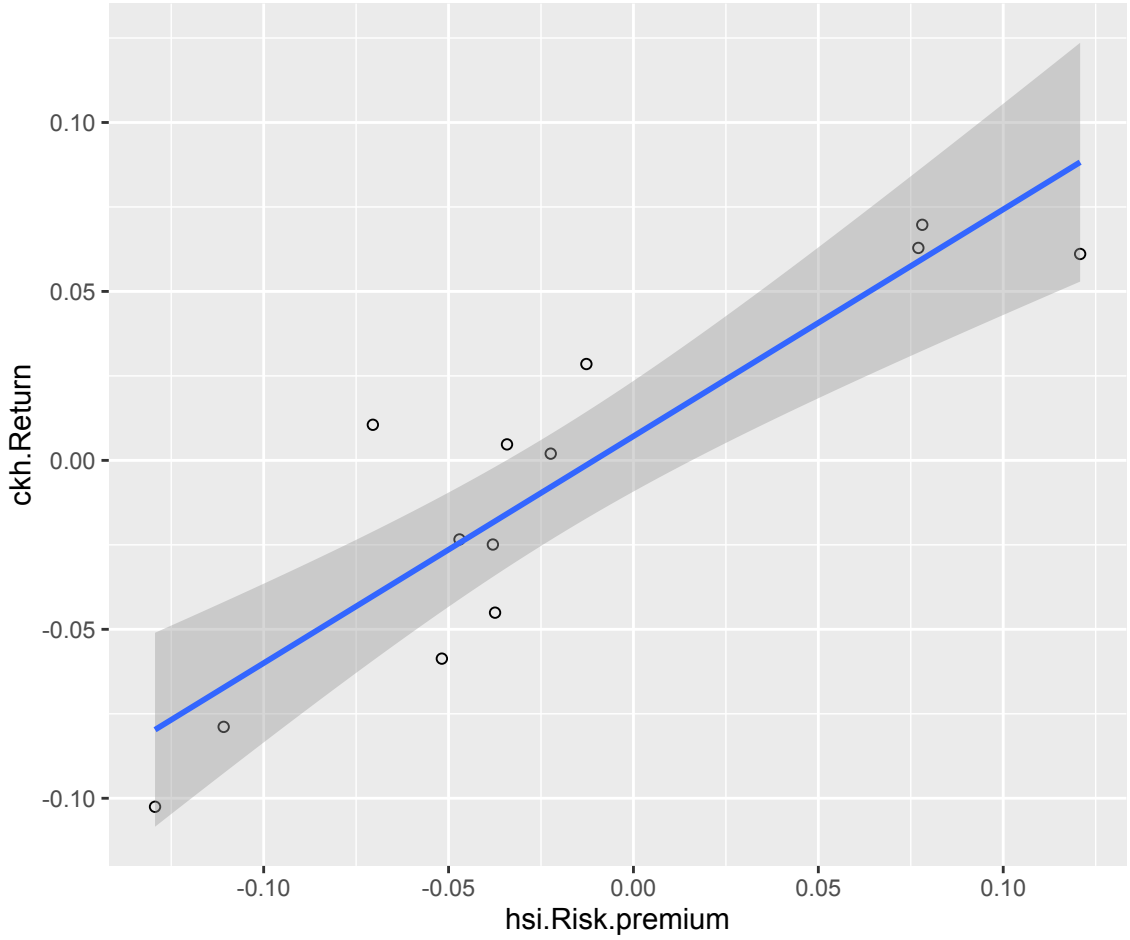
Now we can fit a linear regression. One interesting thing is that in CAPM context the regression line slope can be calculated as $\beta_i = \frac{\sigma_{i,m}}{\sigma_m^2}$.

```
hsi.ckh.returns$hsi.Risk.free <- usa.risk.free + hsi.risk.premium
hsi.ckh.returns$hsi.Risk.premium <- hsi.ckh.returns$hsi.Return - hsi.ckh.returns$hsi.Risk.free
hsi.Return.vector <- as.vector(hsi.ckh.returns$hsi.Return)
ckh.Return.vector <- as.vector(hsi.ckh.returns$ckh.Return)
cov.hsi.ckh <- cov(ckh.Return.vector, hsi.Return.vector)
var.hk <- var(hsi.Return.vector)
capm_beta = cov.hsi.ckh/var.hk

fit <- lm(ckh.Return ~ hsi.Risk.premium, data = hsi.ckh.returns)
summary(fit)
```

```
Call:
lm(formula = ckh.Return ~ hsi.Risk.premium, data = hsi.ckh.returns)

Residuals:
      Min        1Q    Median        3Q       Max
-0.031033 -0.022800  0.001032  0.010137  0.050709

Coefficients:
                 Estimate Std. Error t value Pr(>|t|)
(Intercept)      0.007142   0.007437   0.960    0.357
hsi.Risk.premium 0.671372   0.101209   6.634 3.69e-05 ***
---
Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1

Residual standard error: 0.02565 on 11 degrees of freedom
Multiple R-squared:    0.8, Adjusted R-squared:  0.7818
F-statistic:    44 on 1 and 11 DF,  p-value: 3.692e-05
```

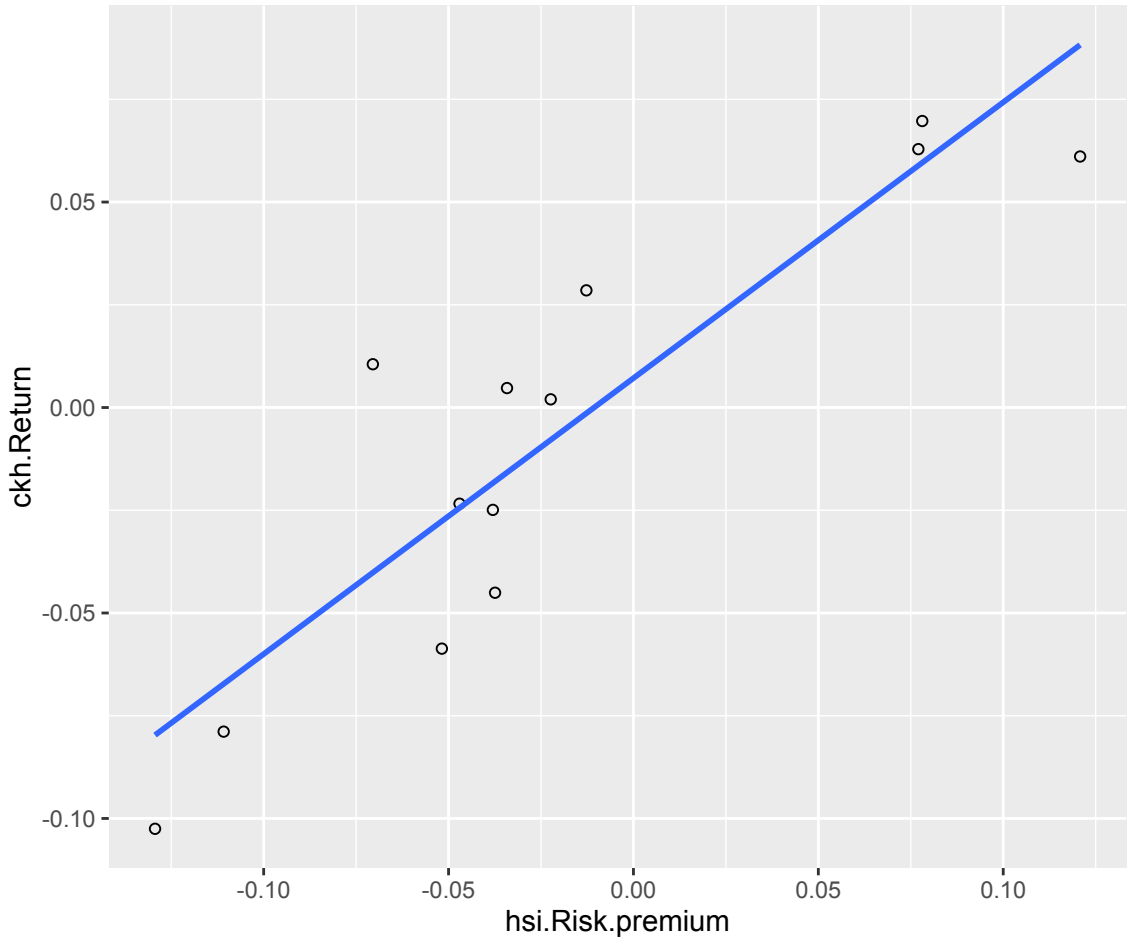
Up to this point we have all we need to plot regressions. We will start with a basic regression plot.

```
p11 <- ggplot(hsi.ckh.returns, aes(x=hsi.Risk.premium, y=ckh.Return)) + geom_point(shape=1) + geom_smoo
p11
```



`geom_smooth` can be customized, for example, not to include the confidence region

```
p11 <- ggplot(hsi.ckh.returns, aes(x=hsi.Risk.premium, y=ckh.Return)) + geom_point(shape=1) + geom_smoo
p11
```

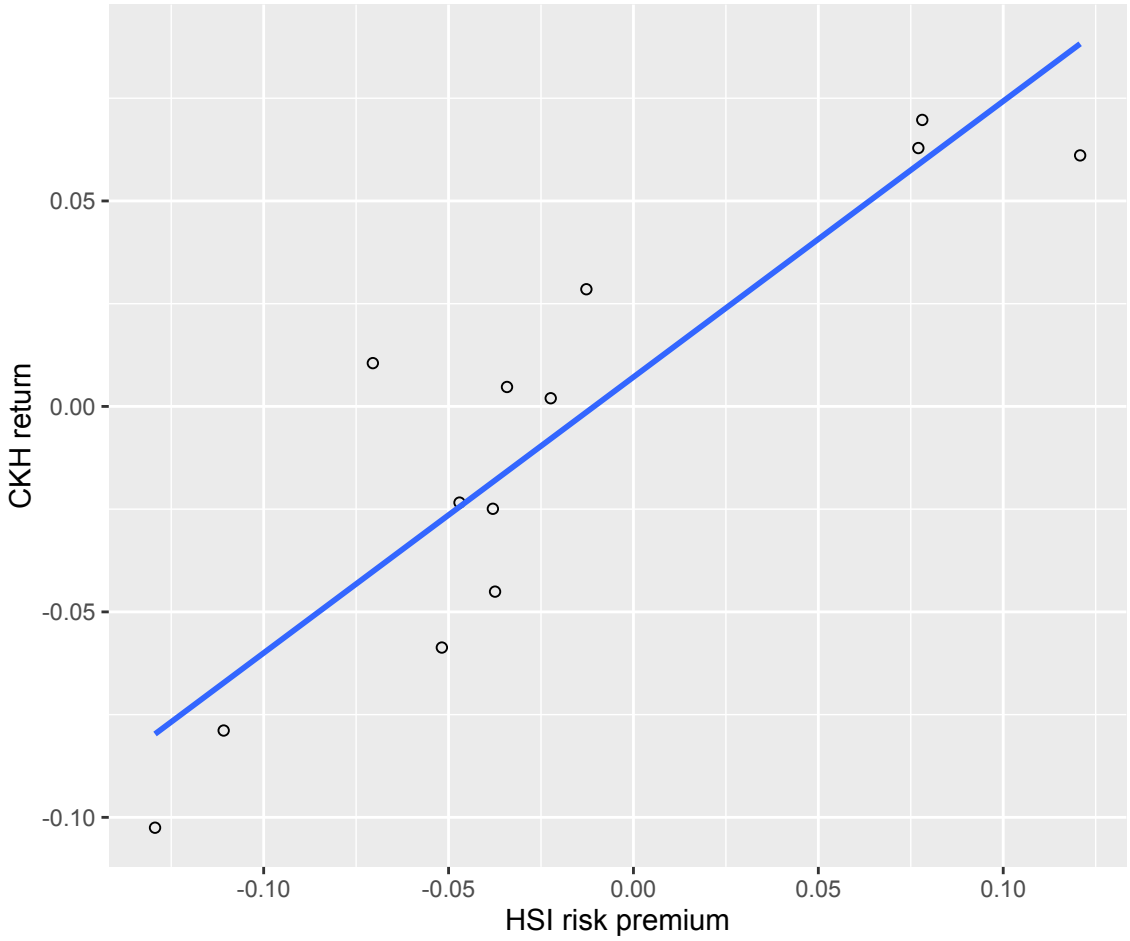


Before continuing it is a good idea to fix the axis labels and add a title.

Customising axis labels

We can change the text of the axis labels using the `scale_x_continuous` and `scale_y_continuous` options, with the names passed as a string to the `name` arguments in each.

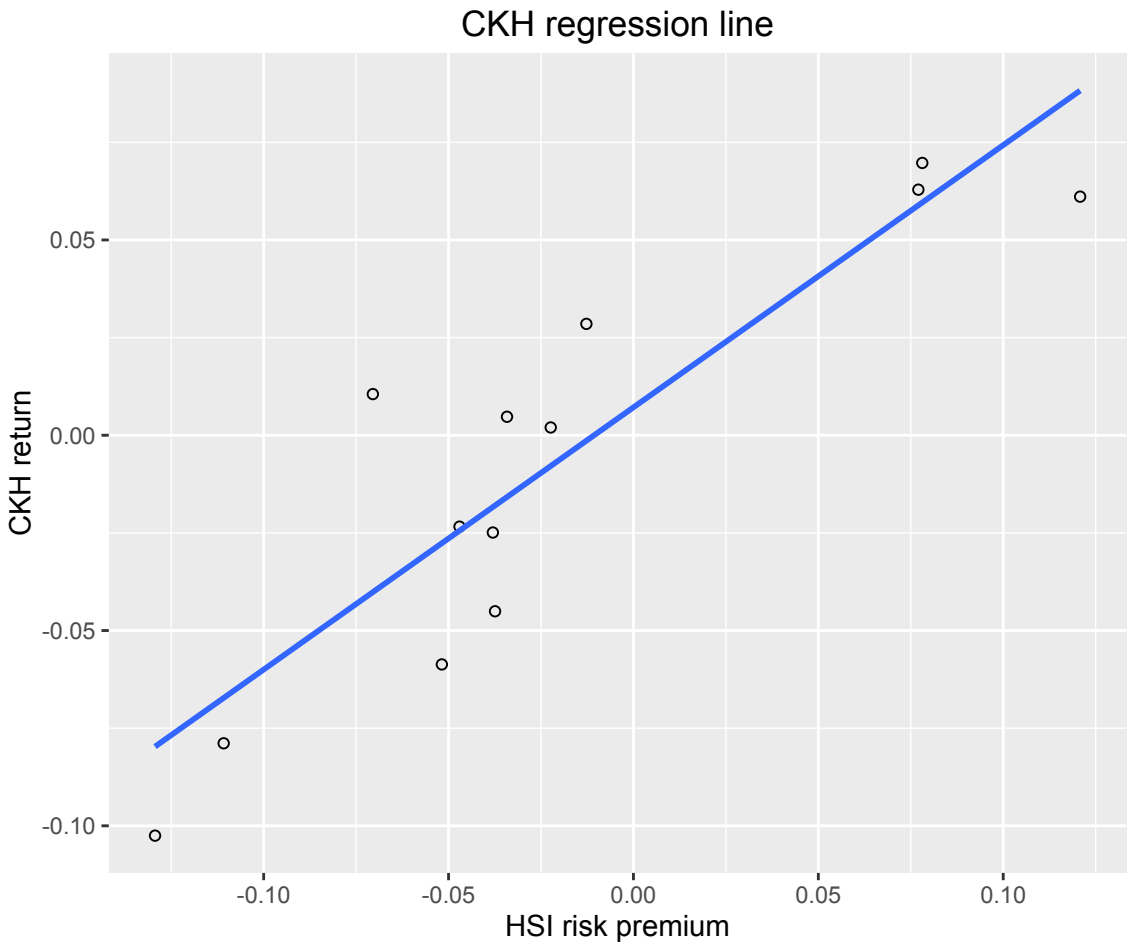
```
p11 <- p11 + scale_x_continuous(name = "HSI risk premium") +
  scale_y_continuous(name = "CKH return")
p11
```



Adding a title

Similarly, we can add a title using the `ggtitle` option.

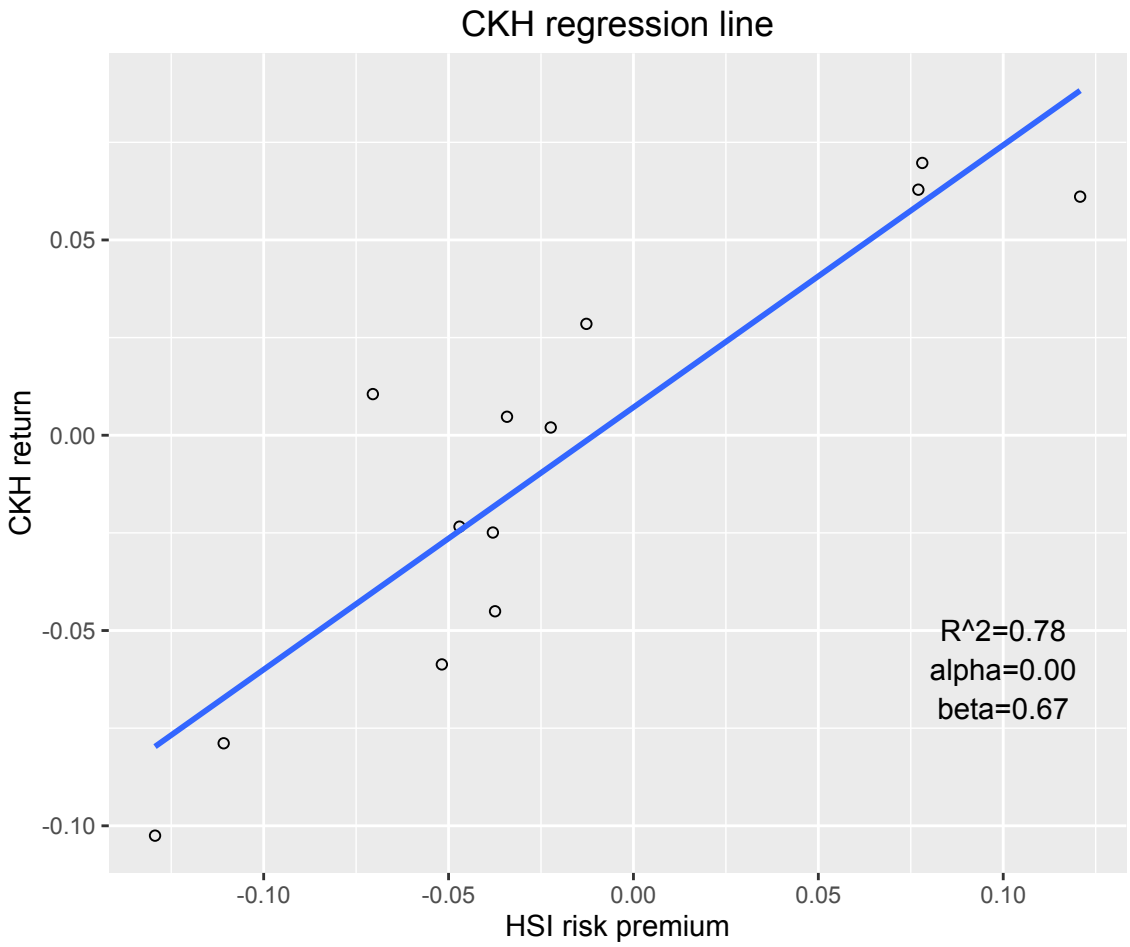
```
p11 <- p11 + ggtitle("CKH regression line")
p11
```



Including regression coefficients

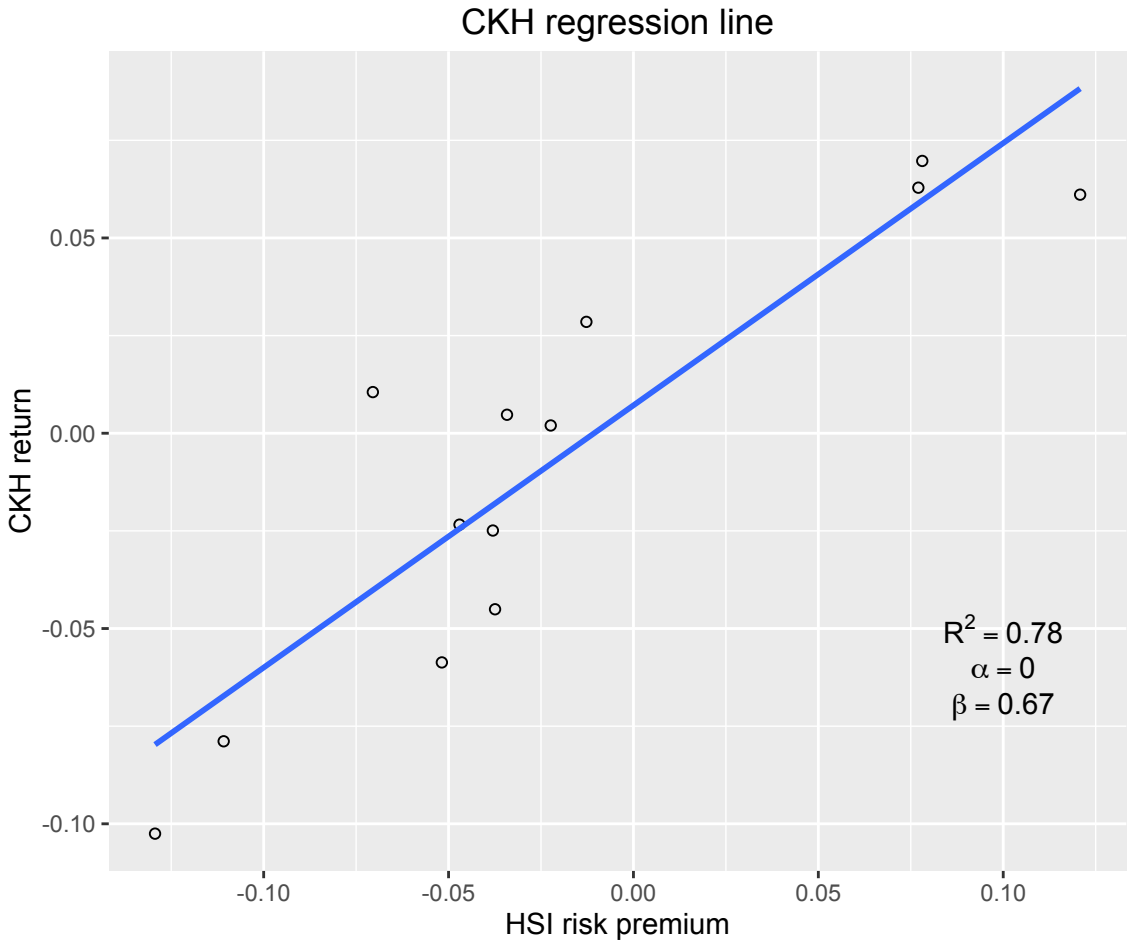
We can also include more information about the regression line itself. It would be interesting to show R^2 and regression coefficients within the plot.

```
p11 <- p11 + annotate("text", x=0.1, y=-0.05, label = "R^2=0.78") +
  annotate("text", x=0.1, y=-0.06, label = "alpha=0.00") +
  annotate("text", x=0.1, y=-0.07, label = "beta=0.67")
p11
```



Another option would be to add greek letters and exponents.

```
p11 <- ggplot(hsi.ckh.returns, aes(x=hsi.Risk.premium, y=ckh.Return)) + geom_point(shape=1) +
  geom_smooth(method=lm, se=FALSE) + ggtitle("CKH regression line") +
  scale_x_continuous(name = "HSI risk premium") +
  scale_y_continuous(name = "CKH return") +
  annotate("text", x=0.1, y=-0.05, label = "R^2 == 0.78", parse=T) +
  annotate("text", x=0.1, y=-0.06, label = "alpha == 0.00", parse=T) +
  annotate("text", x=0.1, y=-0.07, label = "beta == 0.67", parse=T)
p11
```

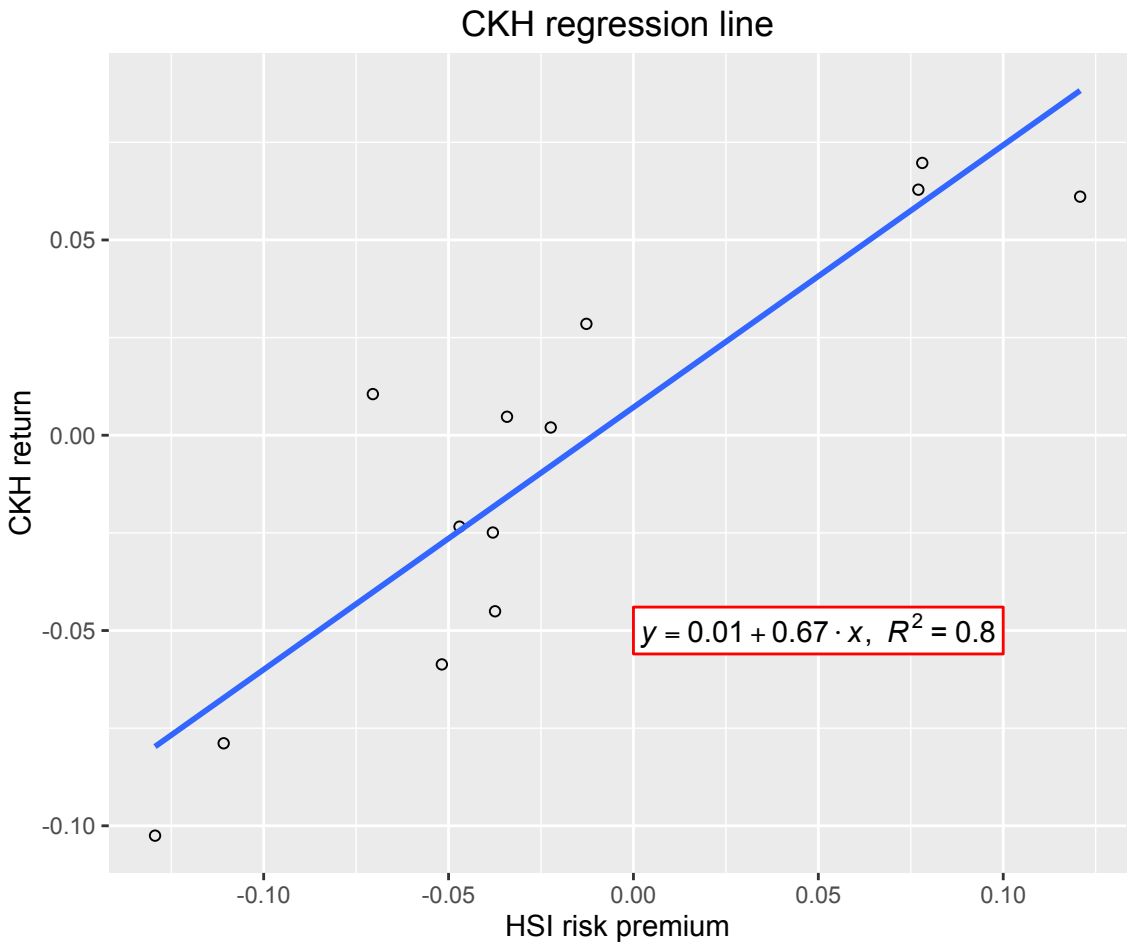


To make the coefficients more clear we will add some elements to increase visibility.

```
p11 <- ggplot(hsi.ckh.returns, aes(x=hsi.Risk.premium, y=ckh.Return)) +
  geom_point(shape=1) + geom_smooth(method=lm, se=FALSE) +
  ggtitle("CKH regression line") +
  scale_x_continuous(name = "HSI risk premium") +
  scale_y_continuous(name = "CKH return") +
  annotate("rect", xmin = 0.075, xmax = 0.125, ymin = -0.075, ymax = -0.045, fill="white",
    colour="red") +
  annotate("text", x=0.1, y=-0.05, label = "R^2 == 0.78", parse=T) + annotate("text", x=0.1, y=-0.06,
    label = "alpha == 0.00", parse=T) +
  annotate("text", x=0.1, y=-0.07, label = "beta == 0.67", parse=T)
p11
```

Another customization could be to show the trend line using rounded digits (or even significant digits) from regression coefficients. This requires us to write a function and is not as easy to obtain as the last plot.

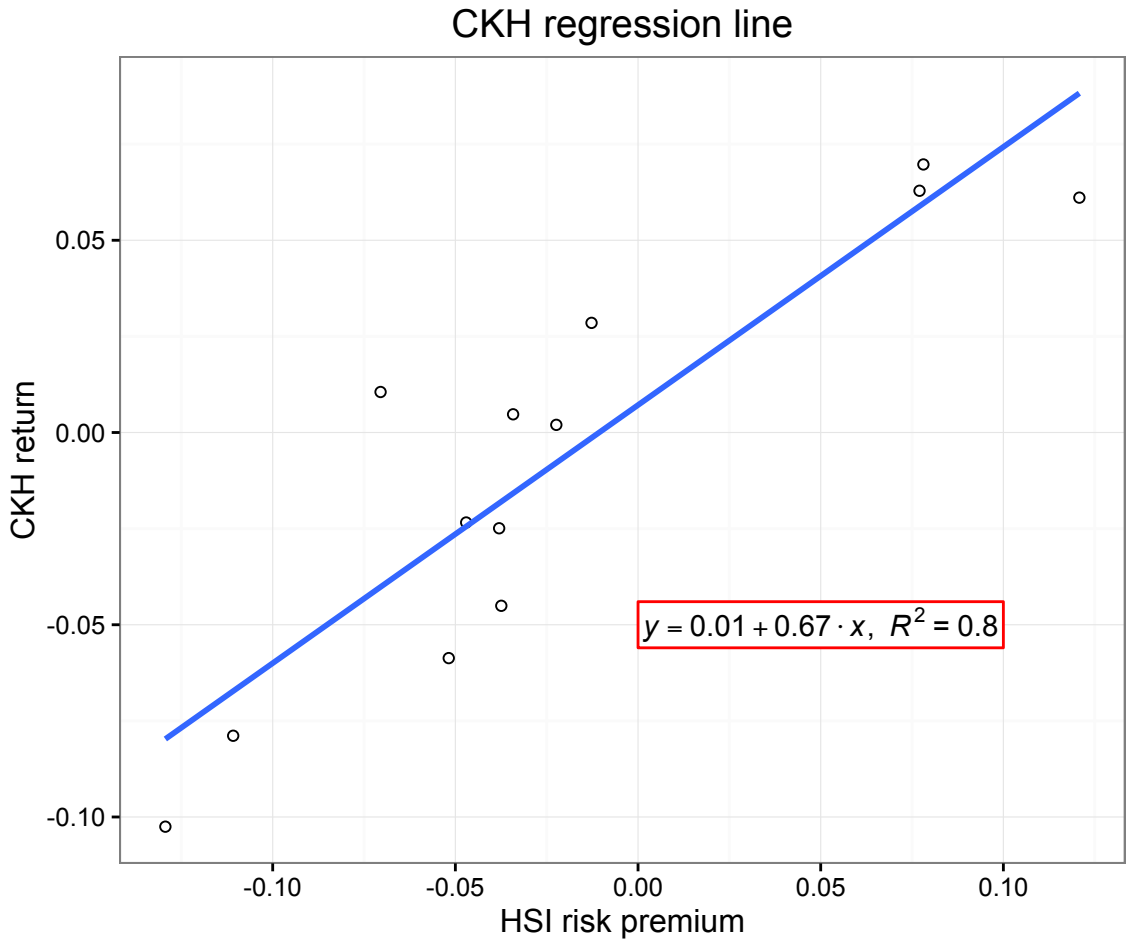
```
equation = function(x) {
  lm_coef <- list(a = round(coef(x)[1], digits = 2),
    b = round(coef(x)[2], digits = 2),
    r2 = round(summary(x)$r.squared, digits = 2));
  lm_eq <- substitute(italic(y) == a + b %.% italic(x)*","~~italic(R)^2~"="~r2,lm_coef)
  as.character(as.expression(lm_eq));
}

p11 <- ggplot(hsi.ckh.returns, aes(x=hsi.Risk.premium, y=ckh.Return)) + geom_point(shape=1) + geom_smoo
  ggtitle("CKH regression line") +
  scale_x_continuous(name = "HSI risk premium") +
  scale_y_continuous(name = "CKH return") +
  annotate("rect", xmin = 0.00, xmax = 0.1, ymin = -0.056, ymax = -0.044, fill="white", colour="red") +
  annotate("text", x = 0.05, y = -0.05, label = equation(fit), parse = TRUE)
p11
```



Using the white theme

As explained in the previous posts, we can also change the overall look of the plot using themes. We'll start using a simple theme customisation by adding `theme_bw()`. As you can see, we can further tweak the graph using the `theme` option, which we've used so far to change the legend.

```
p11 <- p11 + theme_bw()
p11
```

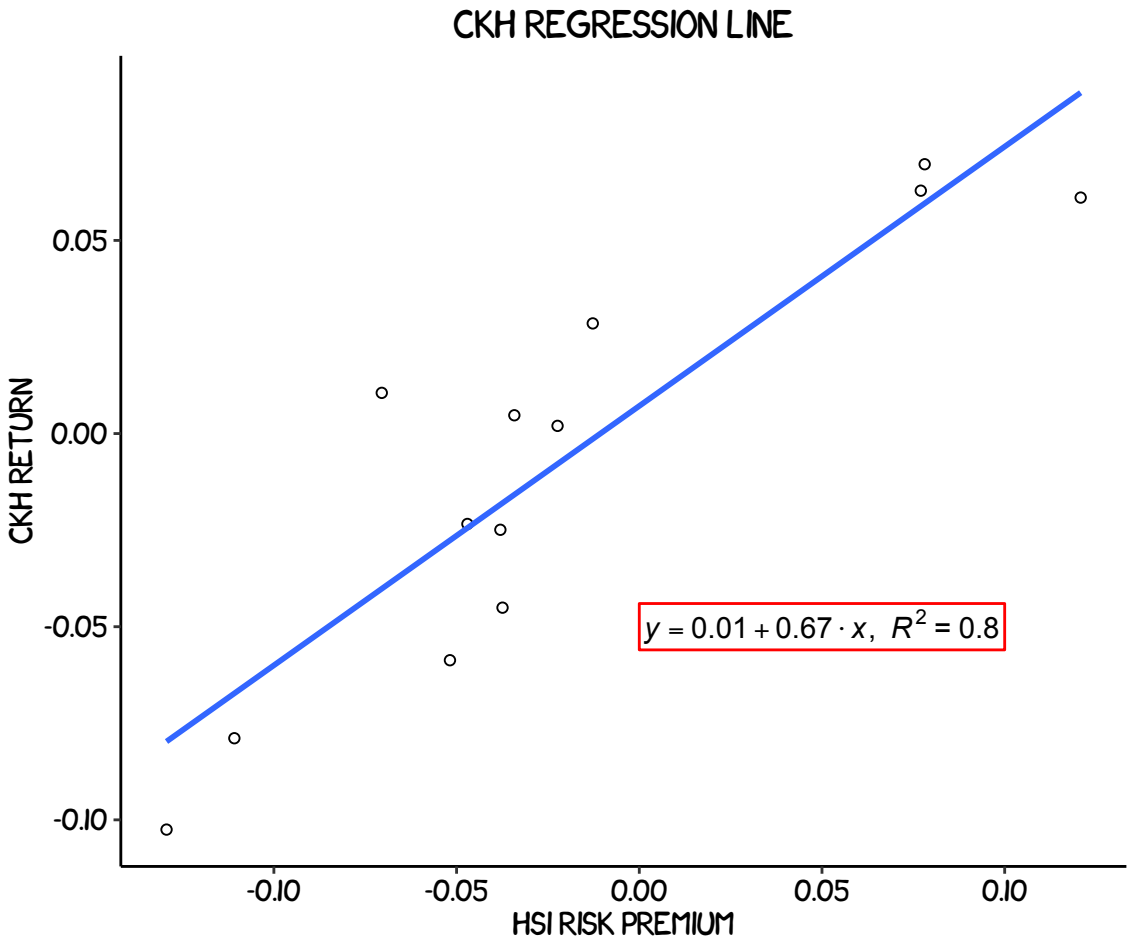


Creating an XKCD style chart

Of course, you may want to create your own themes as well. `ggplot2` allows for a very high degree of customisation, including allowing you to use imported fonts. Below is an example of a theme Mauricio was able to create which mimics the visual style of XKCD. In order to create this chart, you first need to import the XKCD font, and load it into R using the `extrafont` package.

```
p11 <- ggplot(hsi.ckh.returns, aes(x=hsi.Risk.premium, y=ckh.Return)) + geom_point(shape=1) + geom_smoo
  ggtitle("CKH regression line") +
  scale_x_continuous(name = "HSI risk premium") +
  scale_y_continuous(name = "CKH return") +
  annotate("rect", xmin = 0.00, xmax = 0.1, ymin = -0.056, ymax = -0.044, fill="white", colour="red") +
  annotate("text", x = 0.05, y = -0.05, label = equation(fit), parse = TRUE) +
  theme(axis.line.x = element_line(size=.5, colour = "black"),
    axis.line.y = element_line(size=.5, colour = "black"),
    axis.text.x=element_text(colour="black", size = 10),
    axis.text.y=element_text(colour="black", size = 10),
    legend.position="bottom",
    legend.direction="horizontal",
    legend.box = "horizontal",
    legend.key = element_blank(),
    panel.grid.major = element_blank(),
```

```
    panel.grid.minor = element_blank(),
    panel.border = element_blank(),
    panel.background = element_blank(),
    plot.title=element_text(family="xkcd-Regular"),
    text=element_text(family="xkcd-Regular"))
p11
```

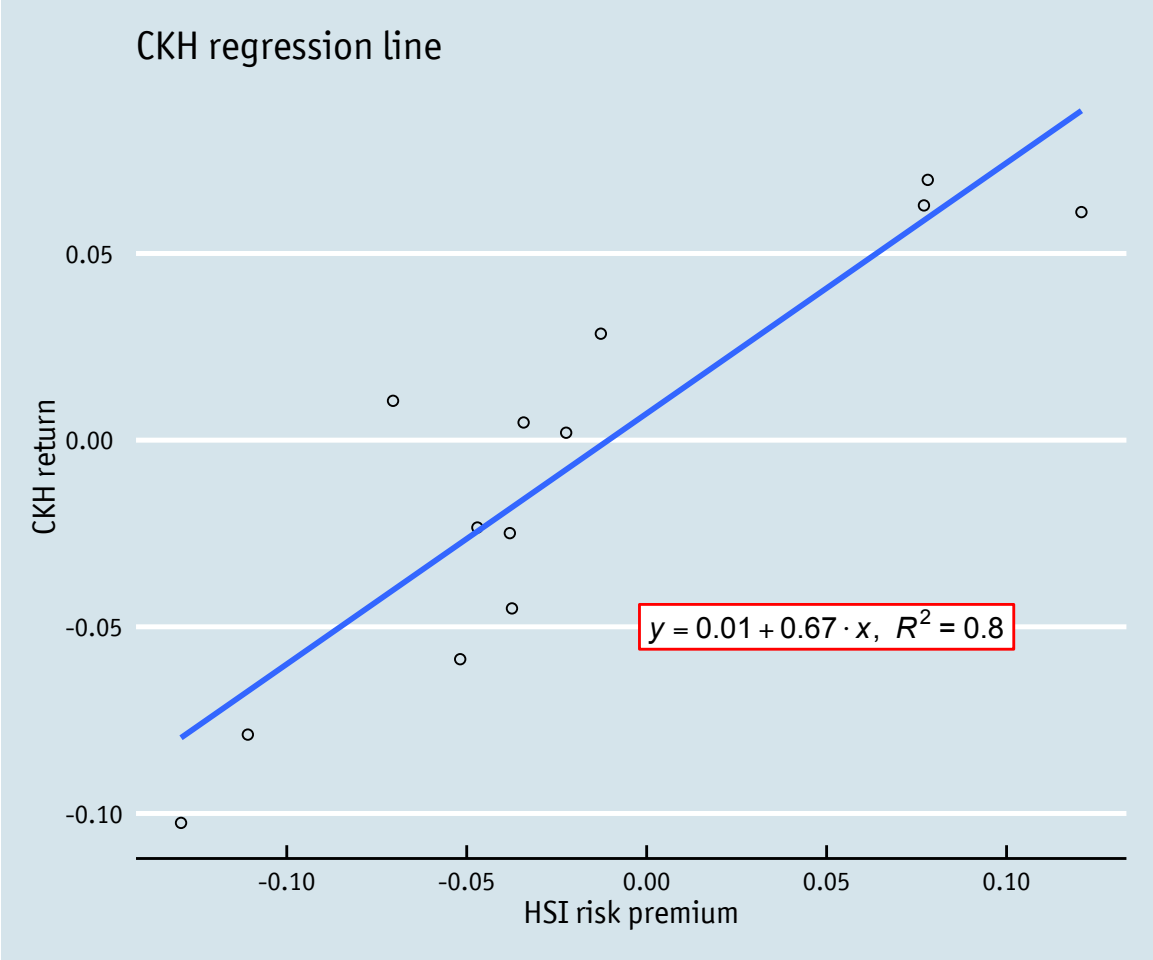


Using 'The Economist' theme

There are a wider range of pre-built themes available as part of the `ggthemes` package (more information on these here). Below we've applied `theme_economist()`, which approximates graphs in the Economist magazine.

```
p11 <- ggplot(hsi.ckh.returns, aes(x=hsi.Risk.premium, y=ckh.Return)) + geom_point(shape=1) + geom_smoo
  ggtitle("CKH regression line") +
  scale_x_continuous(name = "HSI risk premium") +
  scale_y_continuous(name = "CKH return") +
  annotate("rect", xmin = -0.002, xmax = 0.102, ymin = -0.056, ymax = -0.044, fill="white",
    colour="red") +
  annotate("text", x = 0.05, y = -0.05, label = equation(fit), parse = TRUE) +
  theme_economist() + scale_fill_economist() +
```

```
  theme(axis.line.x = element_line(size=.5, colour = "black"),
    axis.title = element_text(size = 12),
    legend.position="bottom",
    legend.direction="horizontal",
    legend.box = "horizontal",
    legend.text = element_text(size = 10),
    text = element_text(family = "OfficinaSanITC-Book"),
    plot.title = element_text(family="OfficinaSanITC-Book"))
p11
```

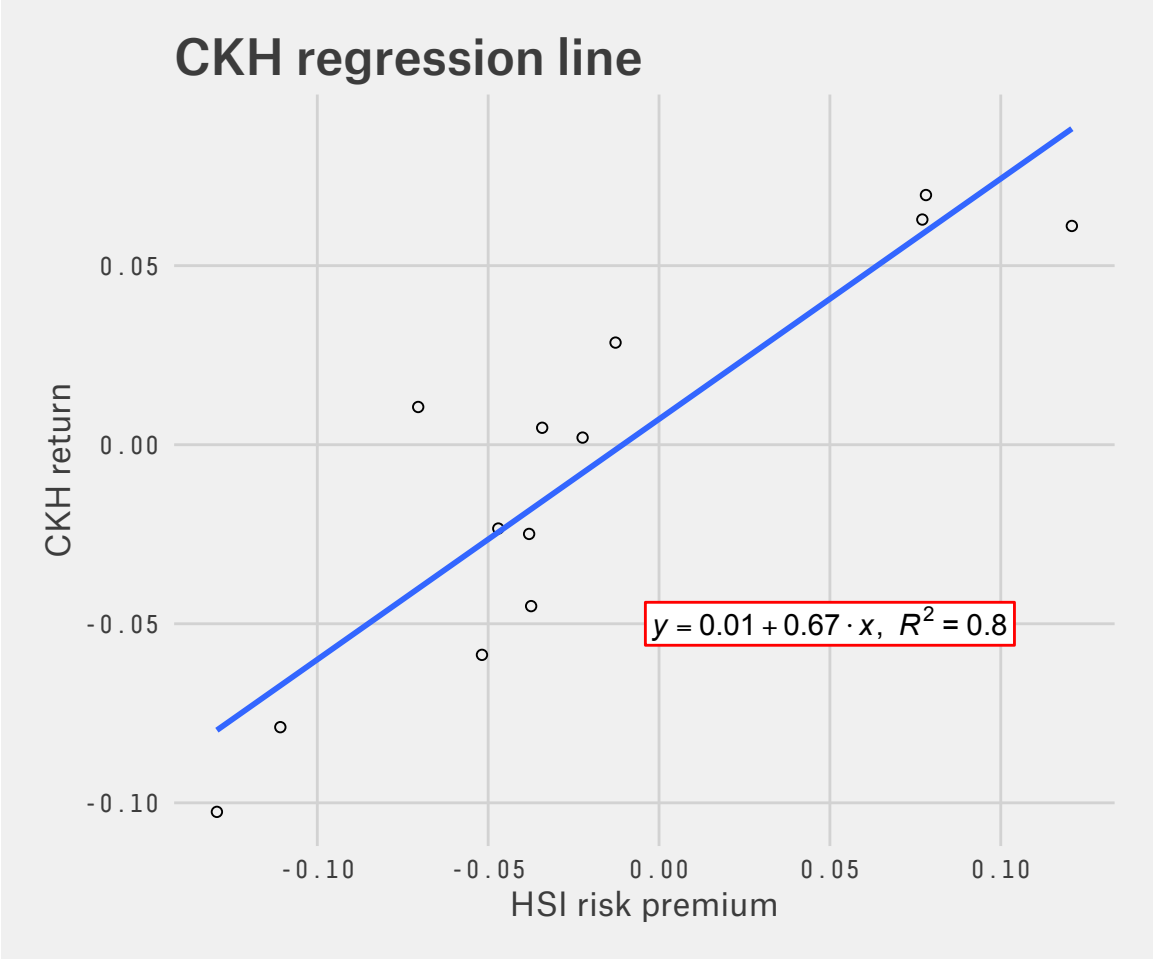


Using 'Five Thirty Eight' theme

Below we've applied `theme_fivethirtyeight()`, which approximates graphs in the nice FiveThirtyEight website. Again, it is also important that the font change is optional and it's only to obtain a more similar result compared to the original. For an exact result you need 'Atlas Grotesk' and 'Decima Mono Pro' which are commercial font and are available here and here.

```
p11 <- ggplot(hsi.ckh.returns, aes(x=hsi.Risk.premium, y=ckh.Return)) + geom_point(shape=1) + geom_smoo
  ggtitle("CKH regression line") +
  scale_x_continuous(name = "HSI risk premium") +
  scale_y_continuous(name = "CKH return") +
```

```
  annotate("rect", xmin = -0.004, xmax = 0.104, ymin = -0.056, ymax = -0.044, fill="white",
    colour="red") +
  annotate("text", x = 0.05, y = -0.05, label = equation(fit), parse = TRUE) +
  theme_fivethirtyeight() + scale_fill_fivethirtyeight() +
  theme(axis.title = element_text(family="Atlas Grotesk Regular"),
    legend.position="bottom",
    legend.direction="horizontal",
    legend.box = "horizontal",
    legend.title=element_text(family="Atlas Grotesk Regular", size = 10),
    legend.text=element_text(family="Atlas Grotesk Regular", size = 10),
    plot.title=element_text(family="Atlas Grotesk Medium"),
    text=element_text(family="DecimaMonoPro"))
p11
```

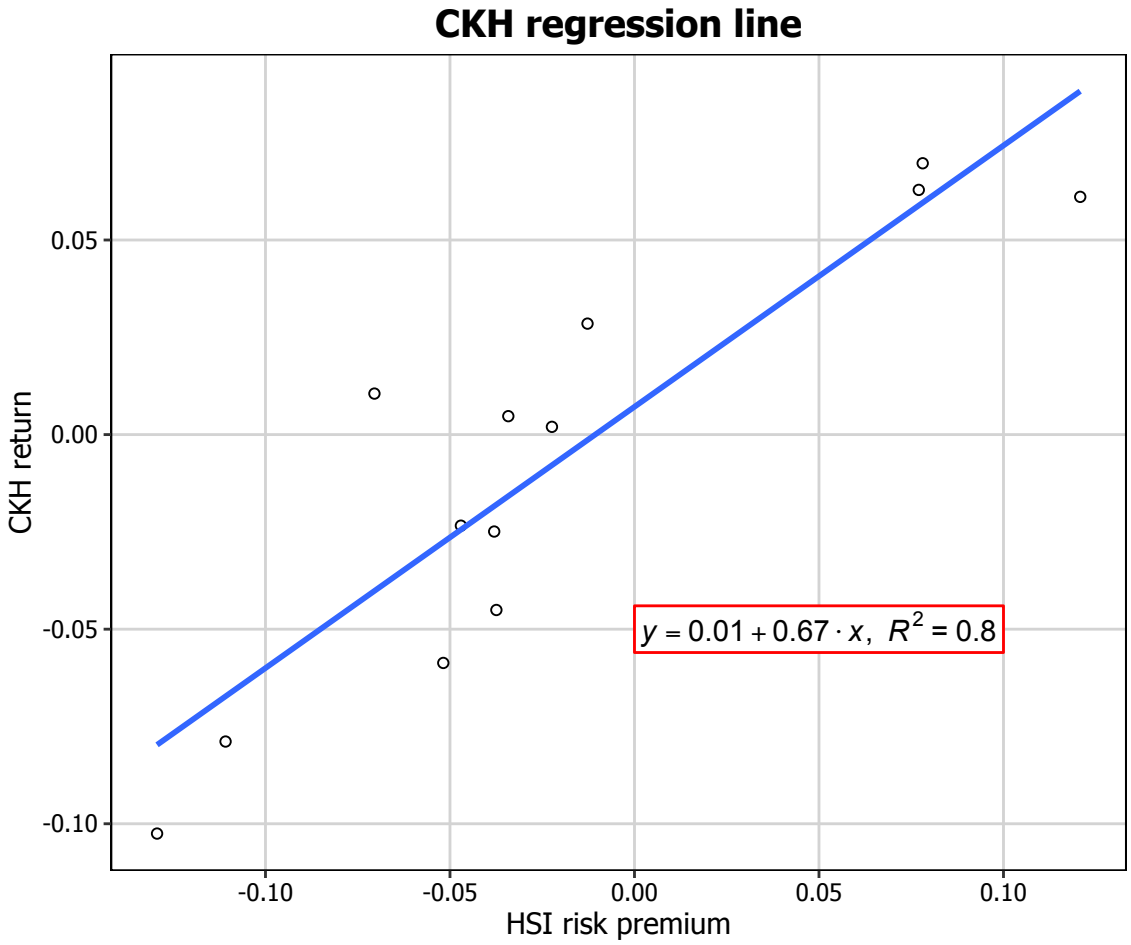


Creating your own theme

As before, you can modify your plots a lot as `ggplot2` allows many customisations. Here is a custom plot where we have modified the axes, background and font.

```
p11 <- ggplot(hsi.ckh.returns, aes(x=hsi.Risk.premium, y=ckh.Return)) + geom_point(shape=1) + geom_smoo
  ggtitle("CKH regression line") +
```

```
  scale_x_continuous(name = "HSI risk premium") +
  scale_y_continuous(name = "CKH return") +
  annotate("rect", xmin = 0.00, xmax = 0.1, ymin = -0.056, ymax = -0.044, fill="white", colour="red") +
  annotate("text", x = 0.05, y = -0.05, label = equation(fit), parse = TRUE) +
  theme(panel.border = element_rect(colour = "black", fill=NA, size=.5),
    axis.text.x=element_text(colour="black", size = 9),
    axis.text.y=element_text(colour="black", size = 9),
    legend.position = "bottom", legend.position = "horizontal",
    panel.grid.major = element_line(colour = "#d3d3d3"),
    panel.grid.minor = element_blank(),
    panel.border = element_blank(), panel.background = element_blank(),
    plot.title = element_text(size = 14, family = "Tahoma", face = "bold"),
    text=element_text(family="Tahoma"))
p11
```

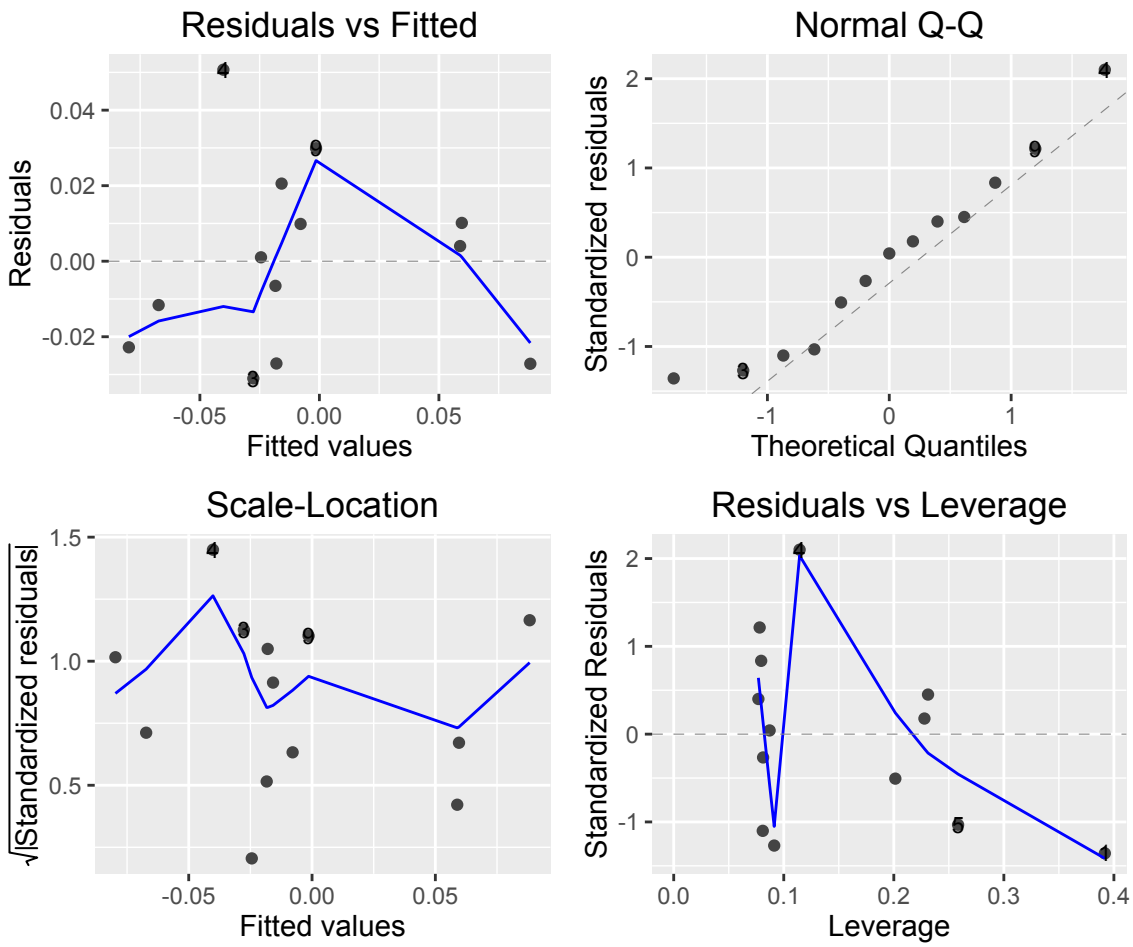


Regression diagnostics plots

Basic diagnostics plots

An important part of creating regression models is evaluating how well they fit the data. We can use the package `ggfortify` to let `ggplot2` interpret `lm` objects and create diagnostic plots.

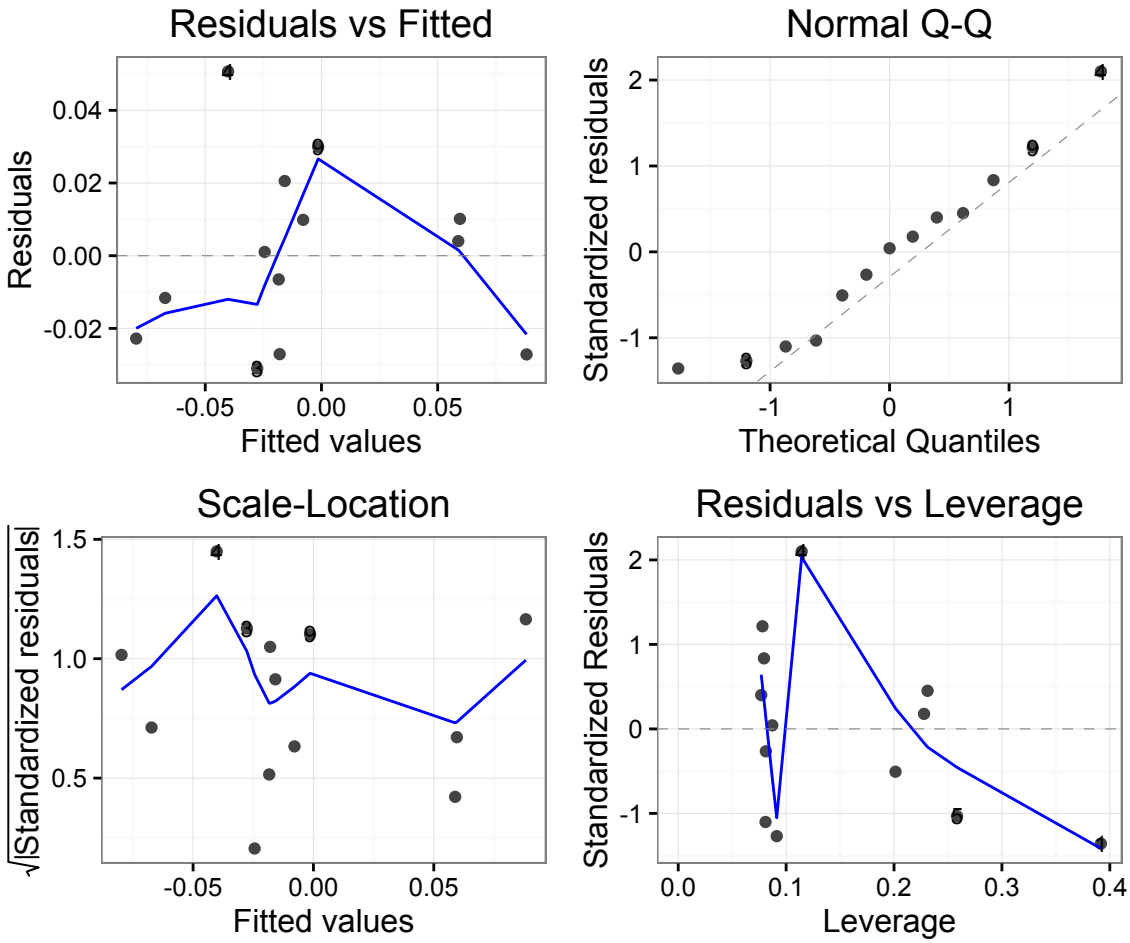
```
autoplot(fit, label.size = 3)
```



Using the white theme

We can also customise the appearance of our diagnostic plots. Let's first use the white theme by again adding `theme_bw()`.

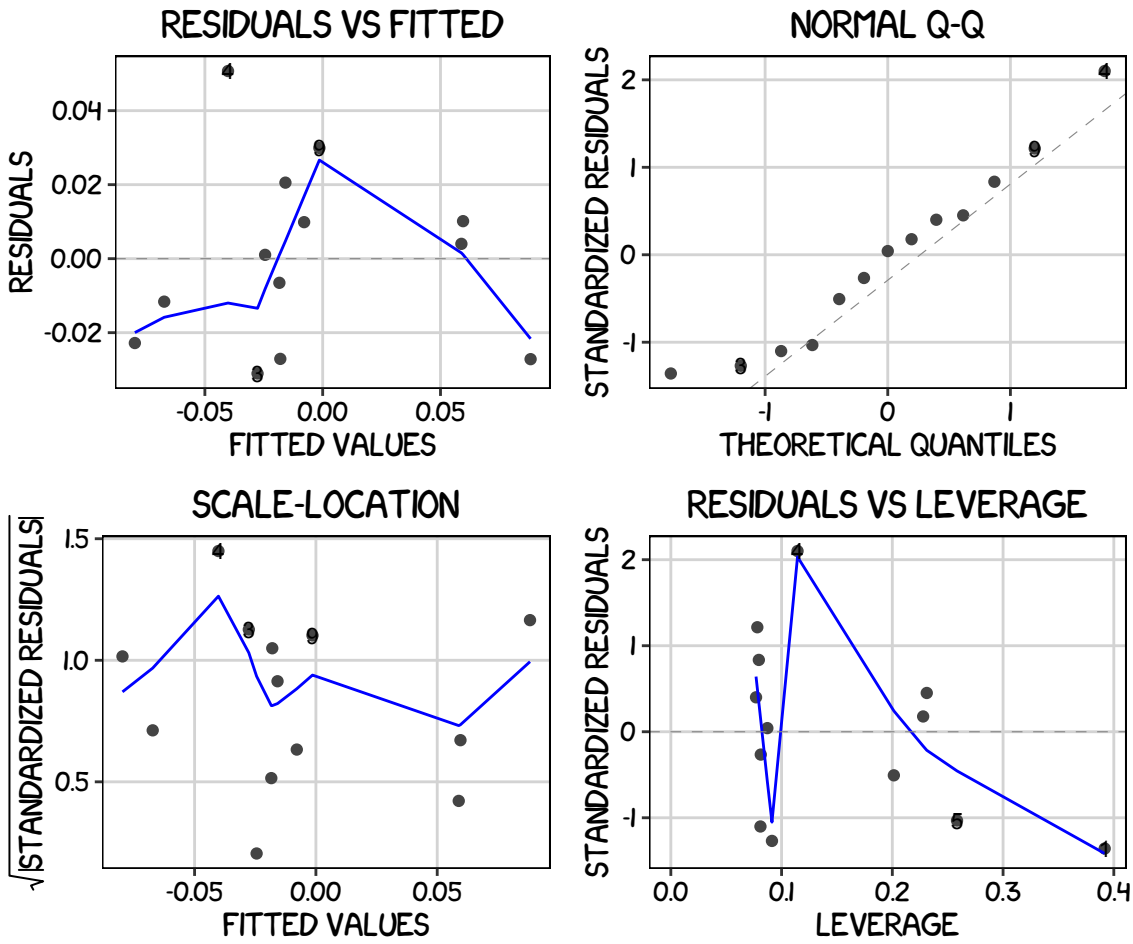
```
autoplot(fit, label.size = 3) + theme_bw()
```



Creating an XKCD style chart

We can of course apply our other themes as well. Let's try the XKCD theme.

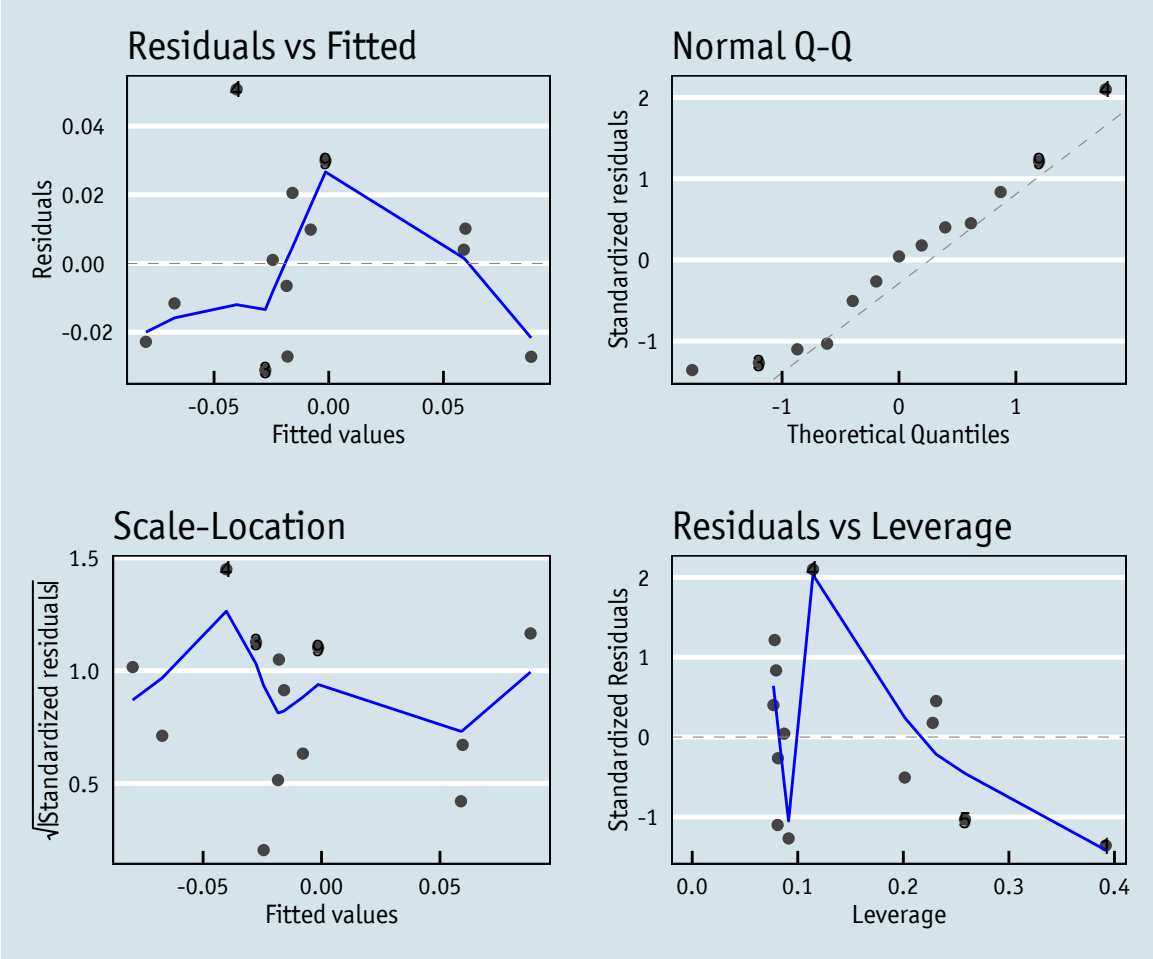
```
autoplot(fit, label.size = 3) + theme(panel.border = element_rect(colour = "black", fill=NA, size=.5),
    axis.text.x=element_text(colour="black", size = 9),
    axis.text.y=element_text(colour="black", size = 9),
    panel.grid.major = element_line(colour = "#d3d3d3"),
    panel.grid.minor = element_blank(),
    panel.border = element_blank(), panel.background = element_blank(),
    plot.title = element_text(family = "xkcd-Regular"),
    text=element_text(family="xkcd-Regular"))
```



Using 'The Economist' theme

And now the Economist theme.

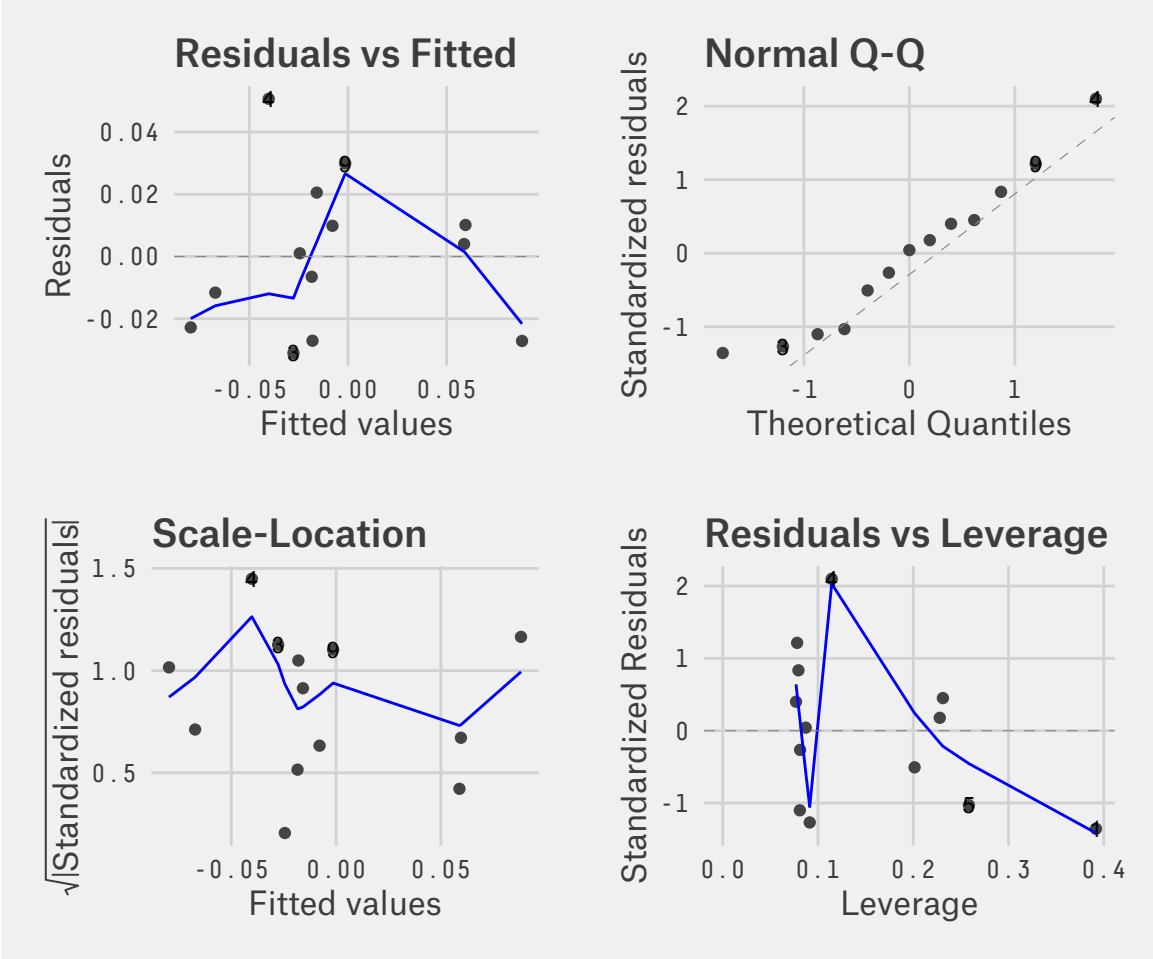
```
autoplot(fit, label.size = 3) + theme_economist() +
  theme(panel.border = element_rect(colour = "black", fill=NA, size=.5),
    axis.text.x=element_text(colour="black", size = 9),
    axis.text.y=element_text(colour="black", size = 9),
    panel.border = element_blank(), panel.background = element_blank(),
    plot.title = element_text(family = "OfficinaSanITC-Book"),
    text=element_text(family="OfficinaSanITC-Book"))
```



Using 'Five Thirty Eight' theme

And now Five Thirty Eight theme.

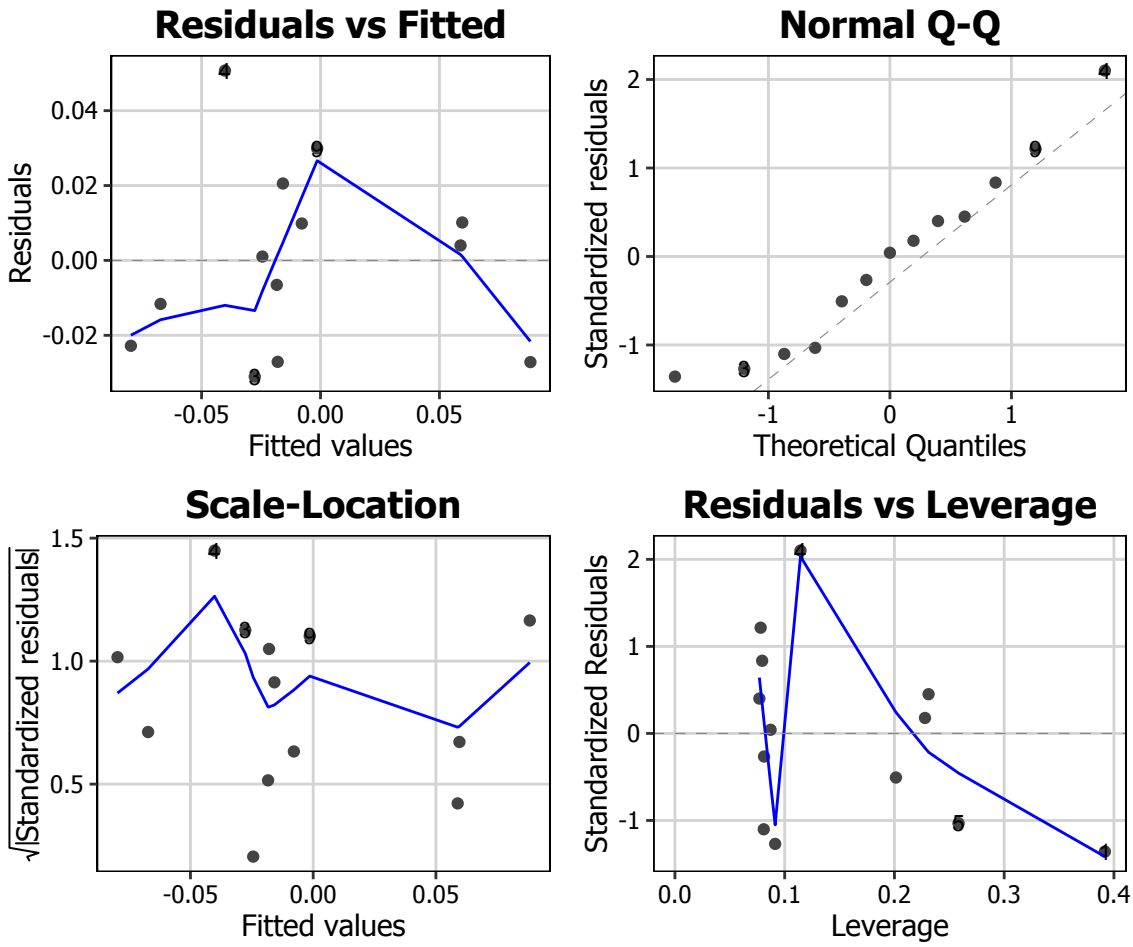
```
autoplot(fit, label.size = 3) + theme_fivethirtyeight() +
  theme(axis.title = element_text(family="Atlas Grotesk Regular"),
    legend.position="bottom",
    legend.direction="horizontal",
    legend.box = "horizontal",
    plot.title=element_text(family="Atlas Grotesk Medium", size = 14),
    text=element_text(family="DecimaMonoPro"))
```



Creating your own theme

Finally, we can also fully customise the diagnostic plots to match our regression plot simply by applying all of the same theme options.

```
autoplot(fit, label.size = 3) + theme(panel.border = element_rect(colour = "black", fill=NA, size=.5),
    axis.text.x=element_text(colour="black", size = 9),
    axis.text.y=element_text(colour="black", size = 9),
    legend.position = "bottom", legend.position = "horizontal",
    panel.grid.major = element_line(colour = "#d3d3d3"),
    panel.grid.minor = element_blank(),
    panel.border = element_blank(), panel.background = element_blank(),
    plot.title = element_text(size = 14, family = "Tahoma", face = "bold"),
    text=element_text(family="Tahoma"))
```


Residuals vs Fitted
Residuals
Fitted values
Normal Q-Q
Standardized residuals
Theoretical Quantiles
Scale-Location
√|Standardized residuals|
Fitted values
Residuals vs Leverage
Standardized Residuals
Leverage