

Week8 IC1 example

```
load("../..//Spring2016/MTH225_Spring2016/EPA_mileage.Rdata")
str(epa)

## 'data.frame': 2884 obs. of 50 variables:
## $ yr      : int  2009 2009 2009 2009 2009 2009 2009 2009 2009 2009 ...
## $ mfr      : int  20 20 20 20 20 20 20 20 20 20 ...
## $ mfr.name : Factor w/ 32 levels "ASTON MARTIN",...: 5 5 5 5 5 5 5 5 5 5 ...
## $ bidx     : int   1 1 3 3 4 4 201 201 202 202 ...
## $ vid      : Factor w/ 686 levels "04-NHW2","05-GRN1",...: 529 529 529 529 524 524 510 ...
## $ cfg      : int   0 0 1 1 2 2 0 0 0 0 ...
## $ carline   : Factor w/ 443 levels "128I","128I CONVERTIBLE",...: 234 234 235 235 234 234 ...
## $ car.truck : Factor w/ 2 levels "C","T": 2 2 2 2 2 2 2 2 2 2 ...
## $ cid      : int  215 215 215 215 144 144 148 148 148 148 ...
## $ police    : Factor w/ 2 levels "N","Y": 1 1 1 1 1 1 1 1 1 1 ...
## $ rhp       : int  235 235 235 235 173 173 220 220 220 220 ...
## $ ec1       : logi  NA NA NA NA NA NA ...
## $ ec2       : logi  NA NA NA NA NA NA ...
## $ ec3       : logi  NA NA NA NA NA NA ...
## $ ec4       : logi  NA NA NA NA NA NA ...
## $ ec5       : logi  NA NA NA NA NA NA ...
## $ evc       : int  102 102 102 102 102 102 102 102 102 102 ...
## $ trns      : Factor w/ 17 levels "A4","A6","AU",...: 7 7 7 7 5 5 5 5 5 5 ...
## $ drv       : Factor w/ 3 levels "4","F","R": 2 2 1 1 2 2 2 2 2 2 ...
## $ od        : int   2 2 2 2 2 2 2 2 2 2 ...
## $ etw       : int  4500 4500 4500 4500 4000 4000 3625 3625 3625 3625 ...
## $ cmp       : num   10 10 10 10 10.5 10.5 9.5 9.5 9.5 9.5 ...
## $ axle      : num   2.24 2.24 2.24 2.24 2.95 2.95 2.69 2.69 2.69 2.69 ...
## $ n.v       : num  28.7 28.7 28.7 28.7 36 36 37.3 37.3 37.7 37.7 ...
## $ a.c       : Factor w/ 2 levels "N","Y": 2 2 2 2 2 2 2 2 2 2 ...
## $ dhp       : num   NA NA NA NA NA NA NA NA NA NA ...
## $ sil       : int   1 1 1 1 1 1 1 1 1 1 ...
## $ prc       : int   3 21 3 21 3 21 3 21 3 21 ...
## $ prp       : int  31 31 32 32 32 32 31 31 31 31 ...
## $ tnum      : int 1083480 1083479 1086540 1086539 1083587 1083586 1051401 1051400 1051401 1051400 ...
## $ fuel      : int   61 61 61 61 61 61 61 61 61 61 ...
## $ C.H       : Factor w/ 2 levels "C","H": 2 1 2 1 2 1 2 1 2 1 ...
## $ avcd      : Factor w/ 3 levels "", "1", "A": 1 1 1 1 1 1 1 1 1 1 ...
## $ wt        : num   NA NA NA NA NA NA NA NA NA NA ...
## $ hc        : num   0.023 0.064 NA NA NA NA 0.002 0.049 0.001 0.037 ...
## $ co        : num   0.4 1.07 NA NA NA NA 0.03 0.5 0.07 0.27 ...
## $ co2       : int  275 459 NA NA NA NA 260 384 260 374 ...
## $ nox       : num   NA 0 NA NA NA NA NA 0.03 NA 0.02 ...
## $ pm        : num   NA NA NA NA NA NA NA NA NA NA ...
## $ mpg       : num  32.2 19.3 29.9 18.4 35 23.8 34.1 23 34.1 23.7 ...
```

```
## $ target.a : num 37.7 37.7 37.7 37.7 28 ...
## $ target.b : num 0.634 0.634 0.634 0.634 0.558 ...
## $ target.c : num 0.024 0.024 0.024 0.024 0.021 ...
## $ set.a : num 13.5 13.5 13.5 13.5 10.8 ...
## $ set.b : num 0.104 0.104 0.104 0.104 0.129 ...
## $ set.c : num 0.0259 0.0259 0.0259 0.0259 0.0181 ...
## $ engine.code: Factor w/ 441 levels "07 L537","1",...: 352 352 354 354 236 236 357 357 357 357 ...
## $ eng.family : Factor w/ 305 levels "9ADXT04.23UD",...: 33 33 33 33 48 48 45 45 47 47 ...
## $ vpc : int 6 6 6 6 4 4 4 4 4 4 ...
## $ cstdwn : num 16.1 16.1 16.1 16.1 17.4 ...
```

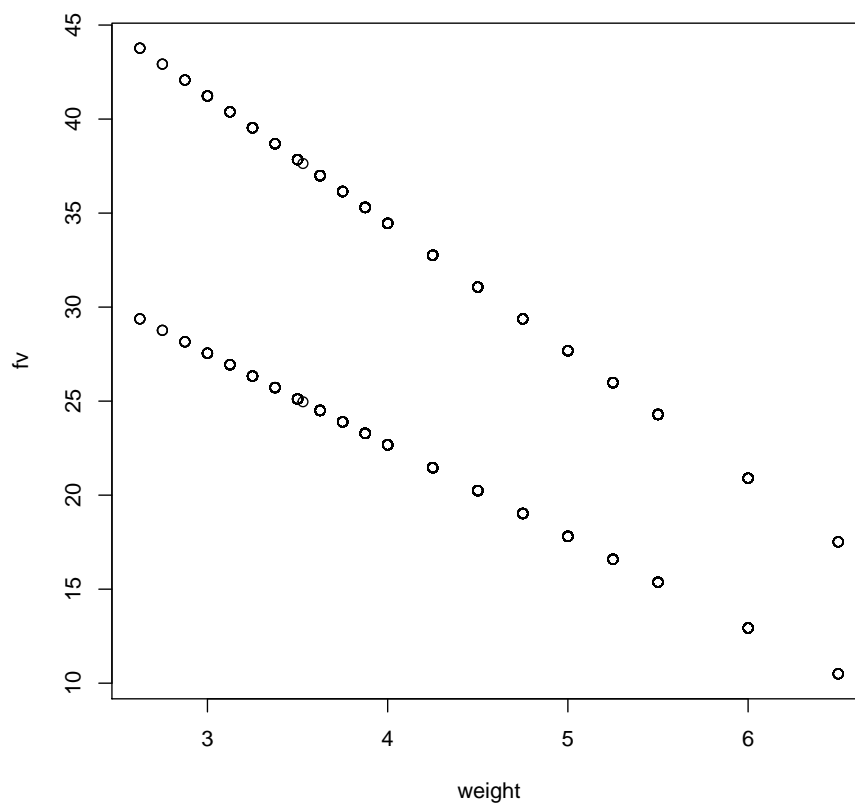
```
cityhighway<-as.numeric(epa$C.H=='H') #city or highway
weight<-epa$etw/1000 #etw has vehicle weight
N<-length(weight) #number of observations
mpg<-epa$mpg
```

Ordinary least squares model

```
lm2<-lm(mpg~epa$C.H*weight)
summary(lm2)

##
## Call:
## lm(formula = mpg ~ epa$C.H * weight)
##
## Residuals:
##      Min       1Q   Median       3Q      Max
## -16.348  -2.073   0.076   2.065  40.270
##
## Coefficients:
##              Estimate Std. Error t value Pr(>|t|)
## (Intercept)    42.1614     0.5645   74.69  <2e-16 ***
## epa$C.HH       19.3937     0.7984   24.29  <2e-16 ***
## weight        -4.8711     0.1275  -38.19  <2e-16 ***
## epa$C.HH:weight -1.9043     0.1805  -10.55  <2e-16 ***
## ---
## Signif. codes:  0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1
##
## Residual standard error: 4.161 on 2880 degrees of freedom
## Multiple R-squared:  0.7666, Adjusted R-squared:  0.7664
## F-statistic: 3153 on 3 and 2880 DF, p-value: < 2.2e-16

fv<-lm2$fitted.values
plot(fv~weight)
```



Call STAN for Bayesian model

```
library(rstan) #make sure rstan is available

## Loading required package: ggplot2
##
## Attaching package: 'ggplot2'
## The following object is masked _by_ '.GlobalEnv':
##
##   mpg
## Loading required package: StanHeaders
## rstan (Version 2.14.1, packaged: 2016-12-28 14:55:41 UTC, GitRev:
## 5fa1e80eb817)
## For execution on a local, multicore CPU with excess RAM we recommend
## calling
## rstan_options(auto_write = TRUE)
## options(mc.cores = parallel::detectCores())
```

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rstan_options(auto_write = TRUE)           #use multiple cores
options(mc.cores = parallel::detectCores()) #if we have them
stanfit<-stan("week8_IC2_covariance_example.stan") #call STAN using defaults

## Warning in readLines(file, warn = TRUE): incomplete final line found
## on '/home/gquinn/Desktop/html/stonehill/mth225/Spring2017/MTH225_Spring2017/week8_IC2_covari

## In file included from /usr/lib64/R/library/RcppEigen/include/Eigen/Core:276:0,
##                  from /usr/lib64/R/library/RcppEigen/include/Eigen/Dense:1,
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math/prim/mat/fun/Eig
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/mat/fun/Eig
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/core/matrix.
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/core.hpp:14,
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/mat.hpp:4,
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math.hpp:4,
##                  from /usr/lib64/R/library/StanHeaders/include/src/stan/model/model_heade
##                  from file5a7e1e70329a.cpp:8:
## /usr/lib64/R/library/RcppEigen/include/Eigen/src/Core/Functors.h:973:28: warning: templat
## struct functor_traits<std::binder2nd<T> >
## ~~~~~
## In file included from /usr/include/c++/6.3.1/bits/stl_function.h:1127:0,
##                  from /usr/include/c++/6.3.1/string:48,
##                  from /usr/include/c++/6.3.1/bits/locale_classes.h:40,
##                  from /usr/include/c++/6.3.1/bits/ios_base.h:41,
##                  from /usr/include/c++/6.3.1/ios:42,
##                  from /usr/include/c++/6.3.1/istream:38,
##                  from /usr/include/c++/6.3.1/sstream:38,
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math/memory/stack_all
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/core/autodif
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/core.hpp:4,
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/mat.hpp:4,
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math.hpp:4,
##                  from /usr/lib64/R/library/StanHeaders/include/src/stan/model/model_heade
##                  from file5a7e1e70329a.cpp:8:
## /usr/include/c++/6.3.1/backward/binders.h:143:11: note: declared here
##     class binder2nd
##     ~~~~~
## In file included from /usr/lib64/R/library/RcppEigen/include/Eigen/Core:276:0,
##                  from /usr/lib64/R/library/RcppEigen/include/Eigen/Dense:1,
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math/prim/mat/fun/Eig
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/mat/fun/Eig
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/core/matrix.
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/core.hpp:14,
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/mat.hpp:4,
##                  from /usr/lib64/R/library/StanHeaders/include/stan/math.hpp:4,
##                  from /usr/lib64/R/library/StanHeaders/include/src/stan/model/model_heade

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##          from file5a7e1e70329a.cpp:8:
## /usr/lib64/R/library/RcppEigen/include/Eigen/src/Core/Functors.h:977:28: warning: template
## struct functor_traits<std::binder1st<T> >
##          ~~~~~~
## In file included from /usr/include/c++/6.3.1/bits/stl_function.h:1127:0,
##          from /usr/include/c++/6.3.1/string:48,
##          from /usr/include/c++/6.3.1/bits/locale_classes.h:40,
##          from /usr/include/c++/6.3.1/bits/ios_base.h:41,
##          from /usr/include/c++/6.3.1/ios:42,
##          from /usr/include/c++/6.3.1/istream:38,
##          from /usr/include/c++/6.3.1/sstream:38,
##          from /usr/lib64/R/library/StanHeaders/include/stan/math/memory/stack_all.h:1,
##          from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/core/autodiff.h:1,
##          from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/core.hpp:4,
##          from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/mat.hpp:4,
##          from /usr/lib64/R/library/StanHeaders/include/stan/math.hpp:4,
##          from /usr/lib64/R/library/StanHeaders/include/src/stan/model/model_header.h:1,
##          from file5a7e1e70329a.cpp:8:
## /usr/include/c++/6.3.1/backward/binders.h:108:11: note: declared here
##      class binder1st
##          ~~~~~~
## In file included from /usr/lib64/R/library/RcppEigen/include/Eigen/Core:326:0,
##          from /usr/lib64/R/library/RcppEigen/include/Eigen/Dense:1,
##          from /usr/lib64/R/library/StanHeaders/include/stan/math/prim/mat/fun/EigenHelpers.h:1,
##          from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/mat/fun/EigenHelpers.h:1,
##          from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/core/matrix.h:1,
##          from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/core.hpp:14,
##          from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/mat.hpp:4,
##          from /usr/lib64/R/library/StanHeaders/include/stan/math.hpp:4,
##          from /usr/lib64/R/library/StanHeaders/include/src/stan/model/model_header.h:1,
##          from file5a7e1e70329a.cpp:8:
## /usr/lib64/R/library/RcppEigen/include/Eigen/src/Core/products/GeneralBlockPanelKernel.h:1:
## /usr/lib64/R/library/RcppEigen/include/Eigen/src/Core/products/GeneralBlockPanelKernel.h:1:
##      if(nr==4) traits.initAcc(C3);
##      ~~
## /usr/lib64/R/library/RcppEigen/include/Eigen/src/Core/products/GeneralBlockPanelKernel.h:1:
##      traits.initAcc(C4);
##      ~~~~~~
## /usr/lib64/R/library/RcppEigen/include/Eigen/src/Core/products/GeneralBlockPanelKernel.h:1:
##      if(nr==4) R3 = ploadu<ResPacket>(r3);
##      ~~
## /usr/lib64/R/library/RcppEigen/include/Eigen/src/Core/products/GeneralBlockPanelKernel.h:1:
##      traits.acc(C0, alphav, R0);
##      ~~~~~~
## /usr/lib64/R/library/RcppEigen/include/Eigen/src/Core/products/GeneralBlockPanelKernel.h:1:

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##         if(nr==4) traits.acc(C3, alphav, R3);
##         ~~
## /usr/lib64/R/library/RcppEigen/include/Eigen/src/Core/products/GeneralBlockPanelKernel.h:
##         pstoreu(r0, R0);
##         ~~~~~~
## In file included from /usr/lib64/R/library/RcppEigen/include/Eigen/SparseLU:29:0,
##         from /usr/lib64/R/library/RcppEigen/include/Eigen/Sparse:22,
##         from /usr/lib64/R/library/StanHeaders/include/stan/math/prim/mat/fun/csr
##         from /usr/lib64/R/library/StanHeaders/include/stan/math/prim/mat.hpp:85,
##         from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/mat.hpp:11,
##         from /usr/lib64/R/library/StanHeaders/include/stan/math.hpp:4,
##         from /usr/lib64/R/library/StanHeaders/include/src/stan/model/model_header
##         from file5a7e1e70329a.cpp:8:
## /usr/lib64/R/library/RcppEigen/include/Eigen/src/SparseLU/SparseLU_gemm_kernel.h: In func
## /usr/lib64/R/library/RcppEigen/include/Eigen/src/SparseLU/SparseLU_gemm_kernel.h:78:9: wa
##         if(RK==4) b30 = pset1<Packet>(Bc0[3]);
##         ~~
## /usr/lib64/R/library/RcppEigen/include/Eigen/src/SparseLU/SparseLU_gemm_kernel.h:79:19: r
##         b01 = pset1<Packet>(Bc1[0]);
##         ~~~
## In file included from /usr/lib64/R/library/BH/include/boost/numeric/ublas/matrix.hpp:19:0,
##         from /usr/lib64/R/library/BH/include/boost/numeric/odeint/util/ublas_wra
##         from /usr/lib64/R/library/BH/include/boost/numeric/odeint.hpp:25,
##         from /usr/lib64/R/library/StanHeaders/include/stan/math/prim/arr/functo
##         from /usr/lib64/R/library/StanHeaders/include/stan/math/prim/arr.hpp:36,
##         from /usr/lib64/R/library/StanHeaders/include/stan/math/prim/mat.hpp:29,
##         from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/mat.hpp:11,
##         from /usr/lib64/R/library/StanHeaders/include/stan/math.hpp:4,
##         from /usr/lib64/R/library/StanHeaders/include/src/stan/model/model_header
##         from file5a7e1e70329a.cpp:8:
## /usr/lib64/R/library/BH/include/boost/numeric/ublas/matrix_expression.hpp: In member func
## /usr/lib64/R/library/BH/include/boost/numeric/ublas/matrix_expression.hpp:2224:17: warnin
##         if (it2_ != it2_end_)
##         ~~
## /usr/lib64/R/library/BH/include/boost/numeric/ublas/matrix_expression.hpp:2227:21: note:
##         if (it2_ != it2_end_) {
##         ~~~
## In file included from /usr/lib64/R/library/BH/include/boost/multi_array/base.hpp:28:0,
##         from /usr/lib64/R/library/BH/include/boost/multi_array.hpp:21,
##         from /usr/lib64/R/library/BH/include/boost/numeric/odeint/util/multi_ar
##         from /usr/lib64/R/library/BH/include/boost/numeric/odeint.hpp:61,
##         from /usr/lib64/R/library/StanHeaders/include/stan/math/prim/arr/functo
##         from /usr/lib64/R/library/StanHeaders/include/stan/math/prim/arr.hpp:36,
##         from /usr/lib64/R/library/StanHeaders/include/stan/math/prim/mat.hpp:29,
##         from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/mat.hpp:11,

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##          from /usr/lib64/R/library/StanHeaders/include/stan/math.hpp:4,
##          from /usr/lib64/R/library/StanHeaders/include/src/stan/model/model_header.hpp:4,
##          from file5a7e1e70329a.cpp:8:
## /usr/lib64/R/library/BH/include/boost/multi_array/concept_checks.hpp: In static member function 'static const boost::multi_array::index_range boost::multi_array::index_range::get_index_range(const boost::multi_array::index_range&)'
## /usr/lib64/R/library/BH/include/boost/multi_array/concept_checks.hpp:42:43: warning: type of 'boost::multi_array::index_range' does not match 'boost::multi_array::index_range'
##         typedef typename Array::index_range index_range;
##         ~~~~~
## /usr/lib64/R/library/BH/include/boost/multi_array/concept_checks.hpp:43:37: warning: type of 'boost::multi_array::index_range' does not match 'boost::multi_array::index_range'
##         typedef typename Array::index index;
##         ~~~~~
## /usr/lib64/R/library/BH/include/boost/multi_array/concept_checks.hpp: In static member function 'static const boost::multi_array::index_range boost::multi_array::index_range::get_index_range(const boost::multi_array::index_range&)'
## /usr/lib64/R/library/BH/include/boost/multi_array/concept_checks.hpp:53:43: warning: type of 'boost::multi_array::index_range' does not match 'boost::multi_array::index_range'
##         typedef typename Array::index_range index_range;
##         ~~~~~
## /usr/lib64/R/library/BH/include/boost/multi_array/concept_checks.hpp:54:37: warning: type of 'boost::multi_array::index_range' does not match 'boost::multi_array::index_range'
##         typedef typename Array::index index;
##         ~~~~~
## In file included from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/core.hpp:42:
##          from /usr/lib64/R/library/StanHeaders/include/stan/math/rev/mat.hpp:4,
##          from /usr/lib64/R/library/StanHeaders/include/stan/math.hpp:4,
##          from /usr/lib64/R/library/StanHeaders/include/src/stan/model/model_header.hpp:4,
##          from file5a7e1e70329a.cpp:8:
## /usr/lib64/R/library/StanHeaders/include/stan/math/rev/core/set_zero_all_adjoints.hpp: At global scope:
## /usr/lib64/R/library/StanHeaders/include/stan/math/rev/core/set_zero_all_adjoints.hpp:14:1:
##     static void set_zero_all_adjoints() {
##     ~~~~~
print(stanfit)

## Inference for Stan model: week8_IC2_covariance_example.
## 4 chains, each with iter=2000; warmup=1000; thin=1;
## post-warmup draws per chain=1000, total post-warmup draws=4000.
##
##              mean se_mean   sd      2.5%      25%      50%      75%
## city          -7.75     0.01 0.56     -8.87     -8.14     -7.76     -7.37
## highway       11.40     0.01 0.57      10.29      11.01      11.39      11.80
## beta_city     -4.89     0.00 0.13      -5.15      -4.98      -4.89      -4.80
## beta_highway  -6.74     0.00 0.13      -6.98      -6.83      -6.74      -6.65
## sigma         4.16     0.00 0.06       4.06       4.13       4.16       4.20
## lp__        -5558.75     0.04 1.60    -5562.80    -5559.54    -5558.43    -5557.57
##
##              97.5% n_eff Rhat
## city          -6.62  1999    1
## highway       12.47  2180    1
## beta_city     -4.64  1993    1
## beta_highway  -6.49  2233    1
## sigma         4.28  2850    1

```

```
## lp__          -5556.64  1587    1
##
## Samples were drawn using NUTS(diag_e) at Mon Mar 13 08:01:38 2017.
## For each parameter, n_eff is a crude measure of effective sample size,
## and Rhat is the potential scale reduction factor on split chains (at
## convergence, Rhat=1).
```

Launch shinystan

```
library(shinystan)                                     #launch shinystan

## Loading required package: shiny
##
## This is shinystan version 2.3.0

launch_shinystan(stanfit)

##
## Creating shinystan object...
##
## Launching ShinyStan interface... for large models this may take
some time.
##
## Listening on http://127.0.0.1:6491
```