Elementary Effects for the BTD Model

Setup packages.

In [78]:
```
require(data.table)
require(magrittr)
require(sensitivity)

require(ggplot2)
```

```
Loading required package: ggplot2
```

Design experiment.

Load input ranges.

In [2]:
```
z.ranges <- fread("input-ranges.tsv")
z.ranges %>% dim
```

```
58  6
```

In [3]:
```
z.ranges[, `:=`(Minimum = 0.6 * Default, Maximum = 1.6 * Default)]
z.ranges[Variable == "random stream", `:=`(Minimum = 0, Maximum = 10)
]
```

One-at a time experiment with 100 repetitions, a la Morris.

In [4]:
```
z.design <- morris(
    NULL,
    factors = z.ranges$Variable,
    r = 100,
    design = list(
        type = "oat",
        levels = mapply(function(t, x0, x1) {
            if (t == "Integer")
                x1 - x0 + 1
            else if (t == "Boolean")
                2
            else
                5
        }, z.ranges$Type, z.ranges$Minimum, z.ranges$Maximum),
        grid.jump = 1
    )
)
z.design$X %>% dim
```

```
5900   58
```

In [5]:
```
write.table(z.design$X, file = "design.tsv", row.names = FALSE, col.n
ames = TRUE, sep = "\t", quote = FALSE)
```

Relate the design to the model's variables.

In [6]:
```
z.inputs <- cbind(
    Run = 1:(dim(z.design$X)[1]),
    data.table(
        sweep(
            sweep(z.design$X, MARGIN = 2, z.ranges$Maximum - z.ranges
$Minimum, `*`),
            MARGIN = 2,
            z.ranges$Minimum,
            `+`
        )
    )
)
z.inputs %>% summary
```

```
     Run       advertising budget aversion to NPV deviation
Min.   :   1   Min.   :300000     Min.   :0.120
1st Qu.:1476   1st Qu.:425000     1st Qu.:0.170
Median :2950   Median :550000     Median :0.220
Mean   :2950   Mean   :539407     Mean   :0.219
3rd Qu.:4425   3rd Qu.:675000     3rd Qu.:0.270
Max.   :5900   Max.   :800000     Max.   :0.320
base external investor ask rate bioproduct long term price
Min.   : 4.800                  Min.   :3000
1st Qu.: 6.800                  1st Qu.:4250
Median : 8.800                  Median :5500
Mean   : 8.999                  Mean   :5287
3rd Qu.:10.800                  3rd Qu.:6750
Max.   :12.800                  Max.   :8000
bioproduct offtake agreement bioproduct performance advantage
Min.   :0.3000               Min.   :0.600
1st Qu.:0.4250               1st Qu.:0.850
Median :0.5500               Median :1.100
Mean   :0.5433               Mean   :1.109
3rd Qu.:0.6750               3rd Qu.:1.350
Max.   :0.8000               Max.   :1.600
bioproduct price fluctuations bioproduct price reversion time
Min.   :0                     Min.   :0.600
1st Qu.:0                     1st Qu.:0.850
Median :0                     Median :1.100
Mean   :0                     Mean   :1.109
3rd Qu.:0                     3rd Qu.:1.350
Max.   :0                     Max.   :1.600
commercial capital cost input commercial fixed operating cost input
Min.   :7.520e+08             Min.   :16200000
1st Qu.:1.065e+09             1st Qu.:22950000
Median :1.379e+09             Median :29700000
Mean   :1.415e+09             Mean   :29026144
3rd Qu.:1.692e+09             3rd Qu.:36450000
Max.   :2.005e+09             Max.   :43200000
commercial plant capacity commercial plant capacity input
Min.   : 438288           Min.   : 438288
1st Qu.: 620908           1st Qu.: 620908
Median : 803528           Median : 803528
Mean   : 800990           Mean   : 774959
3rd Qu.: 986148           3rd Qu.: 986148
Max.   :1168768           Max.   :1168768
commercial plant startup period commercial process yield input
Min.   :1.800                   Min.   :0.2454
1st Qu.:2.550                   1st Qu.:0.3477
Median :3.300                   Median :0.4499
Mean   :3.159                   Mean   :0.4453
3rd Qu.:4.050                   3rd Qu.:0.5522
Max.   :4.800                   Max.   :0.6544
commercial variable operating cost input
Min.   : 453.7
1st Qu.: 642.7
Median : 831.7
Mean   : 824.6
3rd Qu.:1020.8
Max.   :1209.8
custom feedstock long term price change
```

```
Min.   :0
1st Qu.:0
Median :0
Mean   :0
3rd Qu.:0
Max.   :0
custom feedstock maximum fluctuation magnitude
Min.   :0.2850
1st Qu.:0.4037
Median :0.5225
Mean   :0.5335
3rd Qu.:0.6412
Max.   :0.7600
custom feedstock periodic fluctuation magnitude
Min.   :2.100
1st Qu.:2.975
Median :3.850
Mean   :3.868
3rd Qu.:4.725
Max.   :5.600
custom feedstock reversion time custom feedstock starting price
Min.   :0.600                   Min.   : 42.00
1st Qu.:0.850                   1st Qu.: 59.50
Median :1.100                   Median : 77.00
Mean   :1.068                   Mean   : 75.05
3rd Qu.:1.350                   3rd Qu.: 94.50
Max.   :1.600                   Max.   :112.00
elasticity of demand elasticity of supply
Min.   :0.600        Min.   :0.60
1st Qu.:0.850        1st Qu.:0.85
Median :1.100        Median :1.10
Mean   :1.091        Mean   :1.06
3rd Qu.:1.350        3rd Qu.:1.35
Max.   :1.600        Max.   :1.60
expected continuity of government policy expected green premium
Min.   :0.600                            Min.   :0
1st Qu.:0.850                            1st Qu.:0
Median :1.100                            Median :0
Mean   :1.066                            Mean   :0
3rd Qu.:1.350                            3rd Qu.:0
Max.   :1.600                            Max.   :0
feedstock approval maximum cost feedstock approval maximum time
Min.   : 600000                 Min.   :3.000
1st Qu.: 850000                 1st Qu.:4.250
Median :1100000                 Median :5.500
Mean   :1123686                 Mean   :5.386
3rd Qu.:1350000                 3rd Qu.:6.750
Max.   :1600000                 Max.   :8.000
feedstock approval required switch government capital cost share
Min.   :0.600                       Min.   :0.600
1st Qu.:0.600                       1st Qu.:0.850
Median :0.600                       Median :1.100
Mean   :1.092                       Mean   :1.085
3rd Qu.:1.600                       3rd Qu.:1.350
Max.   :1.600                       Max.   :1.600
government operating cost share government operating grant period
Min.   :0.3000                  Min.   :0.900
```

```
 1st Qu.:0.4250                 1st Qu.:1.275
 Median :0.5500                 Median :1.650
 Mean   :0.5571                 Mean   :1.662
 3rd Qu.:0.6750                 3rd Qu.:2.025
 Max.   :0.8000                 Max.   :2.400
 government production incentive government research cost share
 Min.   :0                      Min.   :0.3000
 1st Qu.:0                      1st Qu.:0.4250
 Median :0                      Median :0.5500
 Mean   :0                      Mean   :0.5571
 3rd Qu.:0                      3rd Qu.:0.6750
 Max.   :0                      Max.   :0.8000
 incumbent long term price trend incumbent market share target econom
ic
 Min.   :0.060                  Min.   :0.2400
 1st Qu.:0.085                  1st Qu.:0.3400
 Median :0.110                  Median :0.4400
 Mean   :0.111                  Mean   :0.4231
 3rd Qu.:0.135                  3rd Qu.:0.5400
 Max.   :0.160                  Max.   :0.6400
 incumbent maximum fluctuation incumbent price response magnitude
 Min.   :0.03000               Min.   :0.1200
 1st Qu.:0.04250               1st Qu.:0.1700
 Median :0.05500               Median :0.2200
 Mean   :0.05657               Mean   :0.2217
 3rd Qu.:0.06750               3rd Qu.:0.2700
 Max.   :0.08000               Max.   :0.3200
 incumbent reversion time incumbent starting price initial market siz
e
 Min.   :0.060            Min.   : 960            Min.   : 600000
 1st Qu.:0.085            1st Qu.:1360            1st Qu.: 850000
 Median :0.110            Median :1760            Median :1100000
 Mean   :0.100            Mean   :1742            Mean   :1062542
 3rd Qu.:0.110            3rd Qu.:2160            3rd Qu.:1350000
 Max.   :0.160            Max.   :2560            Max.   :1600000
 investor optimism long term market size market growth rate
 Min.   :0.600     Min.   :18000         Min.   :0.00600
 1st Qu.:0.850     1st Qu.:25500         1st Qu.:0.00850
 Median :1.100     Median :33000         Median :0.01100
 Mean   :1.074     Mean   :32636         Mean   :0.01087
 3rd Qu.:1.350     3rd Qu.:40500         3rd Qu.:0.01350
 Max.   :1.600     Max.   :48000         Max.   :0.01600
 pathway approval maximum cost pathway approval maximum time
 Min.   : 600000               Min.   :3.000
 1st Qu.: 850000               1st Qu.:4.250
 Median :1100000               Median :5.500
 Mean   :1098729               Mean   :5.489
 3rd Qu.:1350000               3rd Qu.:6.750
 Max.   :1600000               Max.   :8.000
 pathway approval required switch payback period multiplier
 Min.   :0.600                   Min.   :0.600
 1st Qu.:0.600                   1st Qu.:0.850
 Median :1.600                   Median :1.100
 Mean   :1.104                   Mean   :1.136
 3rd Qu.:1.600                   3rd Qu.:1.350
 Max.   :1.600                   Max.   :1.600
 product approval maximum cost product approval maximum time
```

```
 Min.   : 600000              Min.   :3.000
 1st Qu.: 850000              1st Qu.:4.250
 Median :1100000              Median :5.500
 Mean   :1071992              Mean   :5.583
 3rd Qu.:1350000              3rd Qu.:6.750
 Max.   :1600000              Max.   :8.000
 product approval required switch random stream
 Min.   :0.600                    Min.   : 0.000
 1st Qu.:0.600                    1st Qu.: 2.000
 Median :0.600                    Median : 4.000
 Mean   :1.058                    Mean   : 4.618
 3rd Qu.:1.600                    3rd Qu.: 7.000
 Max.   :1.600                    Max.   :10.000
 regulatory process starting point required internal return
 Min.   :0.4500                    Min.   :0.04800
 1st Qu.:0.6375                    1st Qu.:0.06800
 Median :0.8250                    Median :0.08800
 Mean   :0.8082                    Mean   :0.08819
 3rd Qu.:1.0125                    3rd Qu.:0.10800
 Max.   :1.2000                    Max.   :0.12800
 required return multiplier retrofit delay   stagegate length
 Min.   :0.600              Min.   :0.3000   Min.   :0.600
 1st Qu.:0.850              1st Qu.:0.4250   1st Qu.:0.850
 Median :1.100              Median :0.5500   Median :1.100
 Mean   :1.112              Mean   :0.5312   Mean   :1.096
 3rd Qu.:1.350              3rd Qu.:0.6750   3rd Qu.:1.350
 Max.   :1.600              Max.   :0.8000   Max.   :1.600
 strategic value to external investors target demo hours target pilot
hours
 Min.   :0                           Min.   :3000      Min.   :1800
 1st Qu.:0                           1st Qu.:4250      1st Qu.:2550
 Median :0                           Median :5500      Median :3300
 Mean   :0                           Mean   :5615      Mean   :3402
 3rd Qu.:0                           3rd Qu.:6750      3rd Qu.:4050
 Max.   :0                           Max.   :8000      Max.   :4800
```

In [7]:
```
write.table(z.inputs, file="inputs.tsv", row.names = FALSE, col.names
= TRUE, sep = "\t", quote = FALSE)
```

Analyze results.

Read design.

In [88]:
```
z.design <- fread("design.tsv")
z.design %>% dim
```

5900 58

Read inputs.

In [5]:
```
z.inputs <- fread("inputs.tsv")
z.inputs %>% dim
```

```
5900  59
```

Read outputs.

In [6]:
```
z.outputs <- fread("outputs.tsv")
z.outputs[Time == 2050] %>% summary
```

```
      Run             Time      abandoning bioproduct actual net incom
e
 Min.   :   1   Min.   :2050   Min.   :0             Min.   :-1.054e+
09
 1st Qu.:1490   1st Qu.:2050   1st Qu.:0             1st Qu.: 0.000e+
00
 Median :3018   Median :2050   Median :0             Median : 0.000e+
00
 Mean   :2976   Mean   :2050   Mean   :0             Mean   : 8.467e+
08
 3rd Qu.:4462   3rd Qu.:2050   3rd Qu.:0             3rd Qu.: 0.000e+
00
 Max.   :5900   Max.   :2050   Max.   :0             Max.   : 9.175e+
09
 bioproduct favorability indicator bioproduct market share economic
 Min.   :0                         Min.   :-31.4743
 1st Qu.:0                         1st Qu.:  0.3758
 Median :0                         Median :  0.5077
 Mean   :0                         Mean   :  0.8113
 3rd Qu.:0                         3rd Qu.:  0.6740
 Max.   :0                         Max.   : 30.0885
 bioproduct market share mass bioproduct selling price with green pre
mium
 Min.   :-1292800.0           Min.   : 2000
 1st Qu.:       0.2           1st Qu.: 3000
 Median :       0.3           Median : 3903
 Mean   :    -866.5           Mean   : 4450
 3rd Qu.:       0.4           3rd Qu.: 5331
 Max.   :       1.1           Max.   :10000
   BS assets            BS equity          commercial plant is built
 Min.   :-2.371e+08   Min.   :-2.371e+08   Min.   :0.0000
 1st Qu.: 6.432e+08   1st Qu.: 6.432e+08   1st Qu.:0.0000
 Median : 1.773e+09   Median : 1.773e+09   Median :0.0000
 Mean   : 6.836e+09   Mean   : 6.836e+09   Mean   :0.2463
 3rd Qu.: 4.220e+09   3rd Qu.: 4.220e+09   3rd Qu.:0.0000
 Max.   : 1.053e+11   Max.   : 1.053e+11   Max.   :1.0000
 commercial plant operation Completed Demoing Completed Piloting
 Min.   :0.0000             Min.   :     0    Min.   :     0
 1st Qu.:0.0000             1st Qu.:  9907    1st Qu.: 11398
 Median :0.0000             Median : 20077    Median : 22799
 Mean   :0.2357             Mean   : 25494    Mean   : 29753
 3rd Qu.:0.0000             3rd Qu.: 35991    3rd Qu.: 42997
 Max.   :1.0000             Max.   :108294    Max.   :135034
 Cumulative Demoing Production Cumulative Production Current Bioprodu
ct Price
 Min.   :      0               Min.   :       0      Min.   : 2000
 1st Qu.: 172813               1st Qu.:  196797      1st Qu.: 3000
 Median : 370138               Median :  513346      Median : 3903
 Mean   : 478561               Mean   : 2193806      Mean   : 4450
 3rd Qu.: 678898               3rd Qu.: 1692658      3rd Qu.: 5331
 Max.   :2081730               Max.   :21236500      Max.   :10000
 Current Custom Feedstock Price current market size economic
 Min.   : -7.039                Min.   :-2.719e+15
 1st Qu.: 42.131                1st Qu.: 2.273e+09
 Median : 61.487                Median : 3.361e+09
 Mean   : 62.516                Mean   :-9.240e+11
 3rd Qu.: 80.723                3rd Qu.: 4.544e+09
```

```
 Max.   :135.896                Max.   : 1.186e+10
 current market size mass demoing complete demoing progress feedstock
price
 Min.   : 504913          Min.   :0.0000   Min.   :0.0000   Min.   :5
44.7
 1st Qu.:1009820          1st Qu.:0.0000   1st Qu.:0.0000   1st Qu.:5
80.2
 Median :1346440          Median :0.0000   Median :0.3767   Median :5
98.3
 Mean   :1537888          Mean   :0.4394   Mean   :0.4904   Mean   :5
98.1
 3rd Qu.:1901730          3rd Qu.:1.0000   3rd Qu.:1.0000   3rd Qu.:6
15.8
 Max.   :4667810          Max.   :1.0000   Max.   :1.0000   Max.   :6
81.8
 granting decision hypothetical net income idealized NPV
 Min.   :0.0000    Min.   :-2.205e+09      Min.   :-6.716e+09
 1st Qu.:0.0000    1st Qu.: 6.659e+08      1st Qu.: 4.419e+08
 Median :1.0000    Median : 1.319e+09      Median : 1.613e+09
 Mean   :0.5839    Mean   : 1.675e+09      Mean   : 4.474e+09
 3rd Qu.:1.0000    3rd Qu.: 2.241e+09      3rd Qu.: 5.352e+09
 Max.   :1.0000    Max.   : 9.175e+09      Max.   : 3.691e+10
 internal project cancelled indicator IS net income
 Min.   :0                              Min.   :-195189000
 1st Qu.:0                              1st Qu.: -35348500
 Median :0                              Median :  -1659070
 Mean   :0                              Mean   : 594575452
 3rd Qu.:0                              3rd Qu.: 364262250
 Max.   :0                              Max.   :6358370000
 long term market share long term market value
 Min.   :0.0000         Min.   :       0
 1st Qu.:0.2405         1st Qu.:      16
 Median :0.3968         Median :    5078
 Mean   :0.3639         Mean   :  517147
 3rd Qu.:0.5127         3rd Qu.:   89068
 Max.   :0.7787         Max.   :32037200
 minimum selling price without green premium payback period
 Min.   :1351                                    Min.   :   0.000
 1st Qu.:1935                                    1st Qu.:   0.000
 Median :2228                                    Median :   4.960
 Mean   :2333                                    Mean   :   7.298
 3rd Qu.:2633                                    3rd Qu.:   9.619
 Max.   :3887                                    Max.   :1172.180
 piloting complete piloting progress   production      profitability
indicator
 Min.   :0.0000    Min.   :0.0000    Min.   :      0   Min.   :0.0000
 1st Qu.:1.0000    1st Qu.:1.0000    1st Qu.:      0   1st Qu.:1.0000
 Median :1.0000    Median :1.0000    Median :      0   Median :1.0000
 Mean   :0.8375    Mean   :0.8386    Mean   : 213209   Mean   :0.8906
 3rd Qu.:1.0000    3rd Qu.:1.0000    3rd Qu.: 170079   3rd Qu.:1.0000
 Max.   :1.0000    Max.   :1.0000    Max.   :1168770   Max.   :1.0000
 Regulatory Costs    smoothed NPV        Stagegates Missed Stages Rem
aining
 Min.   :-1130240   Min.   :-3.375e+09   Min.   :0         Min.   :-
1.0000
 1st Qu.:  -36625   1st Qu.: 4.731e+08   1st Qu.:0         1st Qu.:
0.0000
```

```
 Median :       0   Median : 1.487e+09   Median :0         Median :
0.0000
 Mean   :  208298   Mean   : 3.515e+09   Mean   :0         Mean   :-
0.0196
 3rd Qu.:  453533   3rd Qu.: 3.751e+09   3rd Qu.:0         3rd Qu.:
0.0000
 Max.   : 3263210   Max.   : 3.049e+10   Max.   :0         Max.   :
0.0000
 technology readiness level total approval cost total approval time
 Min.   :6.000              Min.   :-1130240    Min.   :-1.220
 1st Qu.:7.000              1st Qu.:  -36625    1st Qu.: 3.511
 Median :7.753              Median :  638385    Median : 5.611
 Mean   :7.819              Mean   :  707667    Mean   : 6.092
 3rd Qu.:9.000              3rd Qu.: 1263920    3rd Qu.: 8.549
 Max.   :9.000              Max.   : 3786160    Max.   :22.180
 Total Government Grants Total Investment    Working Capital
 Min.   :0.000e+00       Min.   :3.000e+06   Min.   :-2.371e+08
 1st Qu.:0.000e+00       1st Qu.:1.691e+08   1st Qu.: 6.432e+08
 Median :1.112e+09       Median :6.443e+08   Median : 1.773e+09
 Mean   :1.574e+09       Mean   :7.239e+08   Mean   : 6.836e+09
 3rd Qu.:2.597e+09       3rd Qu.:1.048e+09   3rd Qu.: 4.220e+09
 Max.   :8.902e+09       Max.   :3.407e+09   Max.   : 1.053e+11
```

Clean up outputs by filling in missing results with zero cumulative production.

In [51]:
```
z.outputs.clean <- z.outputs[`Time` == 2050, .(Run, `Cumulative Produ
ction`)]
z.outputs.clean <- rbind(
    z.outputs.clean,
    data.table(Run = setdiff(1:5900, z.outputs[`Time` == 2050, `Run`]
), `Cumulative Production` = 0)
)[order(Run)]$`Cumulative Production`
z.outputs.clean %>% summary
```

```
    Min.  1st Qu.   Median     Mean  3rd Qu.     Max.
       0   172776   489195  2086718  1643970 21236500
```

Define functions to compute elementary effects.

In [20]:

```
ind.rep <- function(i, p) {
# indices of the points of the ith trajectory in the DoE
  (1 : (p + 1)) + (i - 1) * (p + 1)
}

ee.oat <- function(X, y) {
  # compute the elementary effects for a OAT design
  p <- ncol(X)
  r <- nrow(X) / (p + 1)

#  if(is(y,"numeric")){
  if(inherits(y, "numeric")){
    one_i_vector <- function(i){
      j <- ind.rep(i, p)
      j1 <- j[1 : p]
      j2 <- j[2 : (p + 1)]
      # return((y[j2] - y[j1]) / rowSums(X[j2,] - X[j1,]))
      return(solve(X[j2,] - X[j1,], y[j2] - y[j1]))
    }
    ee <- vapply(1:r, one_i_vector, FUN.VALUE = numeric(p))
    ee <- t(ee)
    # "ee" is now a (r times p)-matrix.
#  } else if(is(y,"matrix")){
  } else if(inherits(y, "matrix")){
    one_i_matrix <- function(i){
      j <- ind.rep(i, p)
      j1 <- j[1 : p]
      j2 <- j[2 : (p + 1)]
      return(solve(X[j2,] - X[j1,],
                   y[j2, , drop = FALSE] - y[j1, , drop = FALSE]))
    }
    ee <- vapply(1:r, one_i_matrix,
                 FUN.VALUE = matrix(0, nrow = p, ncol = dim(y)[2]))
    # Special case handling for p == 1 and ncol(y) == 1 (in this cas
e, "ee" is
    # a vector of length "r"):
    if(p == 1 && dim(y)[2] == 1){
      ee <- array(ee, dim = c(r, 1, 1))
    }
    # Transpose "ee" (an array of dimensions c(p, ncol(y), r)) to an
 array of
    # dimensions c(r, p, ncol(y)) (for better consistency with the st
andard
    # case that "class(y) == "numeric""):
    ee <- aperm(ee, perm = c(3, 1, 2))
#  } else if(is(y,"array")){
  } else if(inherits(y, "array")){
    one_i_array <- function(i){
      j <- ind.rep(i, p)
      j1 <- j[1 : p]
      j2 <- j[2 : (p + 1)]
      ee_per_3rd_dim <- sapply(1:(dim(y)[3]), function(idx_3rd_dim){
        y_j2_matrix <- y[j2, , idx_3rd_dim]
        y_j1_matrix <- y[j1, , idx_3rd_dim]
        # Here, the result of "solve(...)" is a (p times dim(y)[2])-m
atrix or
```

```
        # a vector of length dim(y)[2] (if p == 1):
        solve(X[j2,] - X[j1,], y_j2_matrix - y_j1_matrix)
      }, simplify = "array")
      if(dim(y)[2] == 1){
        # Correction needed if dim(y)[2] == 1, so "y_j2_matrix" and
        # "y_j1_matrix" have been dropped to matrices (or even vector
s, if also
        # p == 1):
        ee_per_3rd_dim <- array(ee_per_3rd_dim,
                                dim = c(p, dim(y)[2], dim(y)[3]))
      } else if(p == 1){
        # Correction needed if p == 1 (and dim(y)[2] > 1), so "y_j2_m
atrix" and
        # "y_j1_matrix" have been dropped to matrices:
        ee_per_3rd_dim <- array(ee_per_3rd_dim,
                                dim = c(1, dim(y)[2], dim(y)[3]))
      }
      # "ee_per_3rd_dim" is now an array of dimensions
      # c(p, dim(y)[2], dim(y)[3]). Assign the corresponding names fo
r the
      # third dimension:
      if(is.null(dimnames(ee_per_3rd_dim))){
        dimnames(ee_per_3rd_dim) <- dimnames(y)
      } else{
        dimnames(ee_per_3rd_dim)[[3]] <- dimnames(y)[[3]]
      }
      return(ee_per_3rd_dim)
    }
    ee <- sapply(1:r, one_i_array, simplify = "array")
    # Special case handling if "ee" has been dropped to a vector:
#    if(is(ee,"numeric")){
    if (inherits(ee, "numeric")){
      ee <- array(ee, dim = c(p, dim(y)[2], dim(y)[3], r))
      dimnames(ee) <- list(NULL, dimnames(y)[[2]], dimnames(y)[[3]],
NULL)
    }
    # "ee" is an array of dimensions c(p, dim(y)[2], dim(y)[3], r), s
o it is
    # transposed to an array of dimensions c(r, p, dim(y)[2], dim(y)
[3]):
    ee <- aperm(ee, perm = c(4, 1, 2, 3))
  }
  return(ee)
}
```

Compute the elementary effects.

In [54]:
```
z.ee <- ee.oat(z.design, z.outputs.clean)
z.ee %>% dim
```

100 58

Compute mu, mu-start, and sigma.

In [95]:
```
z.mu <- apply(z.ee, 2, mean)
z.mustar <- apply(z.ee, 2, function(x) mean(abs(x)))
z.sigma <- apply(z.ee, 2, sd)
z.result <- data.table(
    variable = names(z.mu),
    mu       = z.mu       ,
    mustar   = z.mustar   ,
    sigma    = z.sigma
)
```

Sort the results in decreasing order of influence.

Interpretations:

- mu: influence of variable
- mustar: influence of variable, accounting for non-monoticity
- sigma: non-linear and interaction effects for variable

In [96]:
```
z.result[, `:=`(`mu rank` = frank(-mu), `mustar rank` = frank(-mustar
), `sigma rank` = frank(-sigma))]
z.result[order(-mustar)]
```

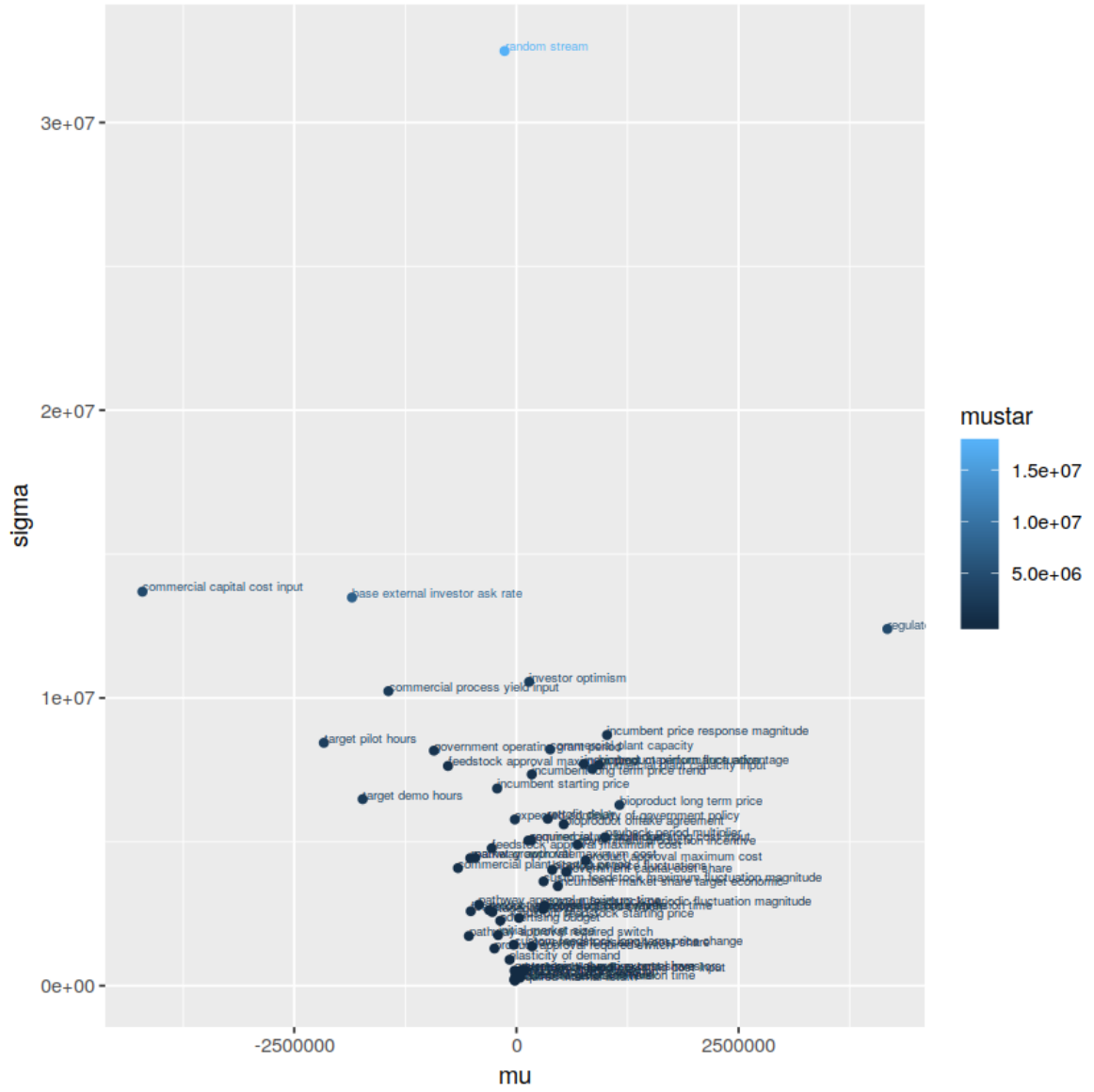
A data.table: 58 x 7

variable	mu	mustar	sigma	mu rank	mustar rank	sigma rank
<chr>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
random stream	-133486.42	17541350.10	32484566.2	38	1	1
base external investor ask rate	-1850318.17	7348024.55	13491334.1	56	2	3
commercial capital cost input	-4207966.84	4334616.68	13694220.0	58	3	2
regulatory process starting point	4174257.64	4289612.44	12396919.7	1	4	4
target pilot hours	-2166769.50	2862255.10	8440518.3	57	5	8
commercial plant capacity	380346.26	2857048.94	8209448.8	14	6	9
investor optimism	142912.96	2727144.16	10559358.6	22	7	5
target demo hours	-1729857.01	2321052.91	6482473.2	55	8	17
commercial process yield input	-1440532.20	2320660.68	10236436.4	54	9	6
bioproduct long term price	1159692.06	2236895.78	6279024.3	2	10	18
commercial plant capacity input	851858.12	1796219.32	7529511.5	6	11	14
incumbent starting price	-217022.16	1444488.88	6851897.6	41	12	16
payback period multiplier	997769.92	1294443.76	5159332.6	4	13	22
government operating grant period	-928596.08	1268723.28	8169127.0	53	14	10
expected continuity of government policy	-17641.56	1211892.04	5776421.8	32	15	20
incumbent price response magnitude	1019687.20	1199229.28	8710859.0	3	16	7
bioproduct performance advantage	928416.05	1157809.73	7679894.7	5	17	12
incumbent long term price trend	172598.68	1061822.04	7343278.9	20	18	15
feedstock approval maximum time	-769938.04	882233.16	7635764.9	52	19	13
feedstock approval maximum cost	-277612.80	850506.40	4775505.9	44	20	26
commercial variable operating cost input	133407.96	850349.32	5044597.4	23	21	24
retrofit delay	351969.48	821691.16	5798967.0	15	22	19
incumbent maximum fluctuation	758617.36	813726.64	7705518.0	8	23	11
product approval maximum cost	778222.36	810382.36	4352778.7	7	24	29
required return multiplier	167171.12	801863.84	5051895.7	21	25	23
government capital cost share	558948.22	773394.70	3956830.0	10	26	32
feedstock approval required switch	-513725.68	753237.56	2589536.2	48	27	39
commercial plant startup period	-657507.52	698248.08	4087269.1	51	28	30
government production incentive	687119.20	687119.20	4897714.9	9	29	25
bioproduct offtake agreement	532557.36	631127.36	5607602.9	11	30	21
pathway approval required switch	-535228.88	575560.06	1726092.4	50	31	44

variable	mu	mustar	sigma	mu rank	mustar rank	sigma rank
<chr>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
market growth rate	-519236.12	519236.12	4433164.2	49	32	28
pathway approval maximum cost	-463430.32	489200.32	4443983.2	47	33	27
incumbent market share target economic	465681.84	465681.84	3459299.6	12	34	34
pathway approval maximum time	-421104.88	438102.08	2817063.5	46	35	35
custom feedstock maximum fluctuation magnitude	306006.56	428637.36	3622887.6	17	36	33
bioproduct price fluctuations	402616.00	402616.00	4026160.0	13	37	31
product approval required switch	-247180.23	369063.61	1293263.9	42	38	47
bioproduct price reversion time	301146.72	367441.36	2657513.1	18	39	37
custom feedstock starting price	28077.08	349222.68	2354480.8	28	40	41
custom feedstock periodic fluctuation magnitude	316337.16	337132.52	2783229.1	16	41	36
product approval maximum time	-307596.04	331842.36	2628612.8	45	42	38
advertising budget	-181763.40	298441.56	2257347.7	39	43	42
stagegate length	-271301.04	284275.76	2559691.6	43	44	40
custom feedstock long term price change	-30893.04	234959.76	1422994.7	36	45	45
initial market size	-206129.72	206129.72	1758005.1	40	46	43
government research cost share	175235.64	175235.64	1362418.6	19	47	46
elasticity of demand	-76722.56	174867.36	902963.6	37	48	48
strategic value to external investors	93145.52	93145.52	542683.2	24	49	49
government operating cost share	-20673.64	89183.96	520963.7	34	50	50
elasticity of supply	18927.60	79720.00	497590.7	29	51	52
commercial fixed operating cost input	40247.60	58322.80	500877.2	26	52	51
aversion to NPV deviation	-9178.76	55051.88	349351.7	30	53	54
long term market size	43178.80	43178.80	431788.0	25	54	53
expected green premium	38939.60	38939.60	275832.3	27	55	55
custom feedstock reversion time	-22584.96	22584.96	225849.6	35	56	56
incumbent reversion time	-19358.24	19358.24	193582.4	33	57	57
required internal return	-17419.32	17419.32	174193.2	31	58	58

Plot mu vs sigma.

In [90]:
```
ggplot(z.result, aes(x = mu, y = sigma, color = mustar, label = variable)) +
    geom_point() +
    geom_text(size = 2, hjust = 0, vjust = 0)
```



In [ ]: