

Sobol Sensitivity Indices for the BTD Model

Setup packages.

```
In [1]: require(data.table)
require(magrittr)
require(rpart)
require(sensitivity)
require(SobolSequence)

require(ggplot2)
```

```
Loading required package: data.table
Loading required package: magrittr
Loading required package: rpart
Loading required package: sensitivity
Registered S3 method overwritten by 'sensitivity':
  method      from
  print.src  dplyr
Loading required package: SobolSequence
Loading required package: ggplot2
```

Read files.

Read design.

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

```
2500 64
```

```
In [3]: n <- dim(z.design)[1]
k <- dim(z.design)[2] / 2
```

Read inputs.

```
In [4]: z.inputs <- fread("inputs-si.tsv")
z.inputs %>% dim
```

```
85000 33
```

```
In [5]: z.inputs %>% colnames
```

```
'Run' 'aversion to NPV deviation' 'base external investor ask rate'  
'bioproduct long term price' 'bioproduct performance advantage'  
'commercial capital cost input' 'commercial plant capacity'  
'commercial plant capacity input' 'commercial process yield input'  
'commercial variable operating cost input' 'expected continuity of government policy'  
'government capital cost share' 'government production incentive' 'initial market size'  
'management response time' 'market growth rate' 'minimum runway'  
'number of missed stagegates allowed' 'payback period multiplier'  
'pilot and demo response time' 'pilot capacity' 'piloting acceptable rate'  
'piloting failure default recovery time' 'piloting failure distribution max' 'random stream'  
'required internal return' 'required return multiplier' 'researching impact on piloting'  
'startup piloting period' 'startup piloting rate' 'strategic value to external investors'  
'target demo hours' 'target pilot hours'
```

Read outputs.

```
In [6]: z.outputs <- fread("outputs-si-wide.tsv")  
z.outputs %>% dim
```

```
2720000 53
```

```
In [7]: z.outputs %>% colnames
```

```
'Replacement' 'Scale' 'Run' 'Time' 'bioproduct market share mass'  
'current market size economic' 'current market size mass' 'long term market share'  
'long term market value' 'Adopters' 'NonAdopters' 'Potential Adopters'  
'abandoning bioproduct' 'Cumulative Demoing Production' 'Cumulative Production'  
'prepiloting' 'pilot plant construction' 'pilot plant is built' 'startup piloting complete'  
'piloting ongoing' 'piloting progress' 'piloting complete' 'predemoing'  
'demo plant construction' 'demo plant is built' 'regulatory process ongoing'  
'startup demoing completed' 'demoing ongoing' 'demoing progress' 'demoing complete'  
'regulatory delay' 'precommercial' 'commercial plant construction'  
'commercial plant is built' 'commercial plant operation' 'technology readiness level'  
'stage in progress' 'BS equity' 'payback period' 'NPV at required return'  
'profitability indicator' 'bioproduct favorability indicator'  
'long term selling price without green premium after market entry' 'total approval cost'  
'total approval time' 'in business indicator' 'internal project cancelled indicator' 'investing'  
'granting' 'Total Government Grants' 'Total Investment' 'Working Capital'  
'IS production incentive'
```

Take a simpler subset.

- Since the four base cases give very similar results, just use one of them.
- For now, just look at 2050.

```
In [8]: yy <- z.outputs[  
    Replacement == "Advantaged" & Scale == "Niche" & Time == 2050,  
]  
yy %>% dim
```

```
85000 53
```

Split the input into x_A and x_B .

```
In [9]: xa <- z.inputs[1:2500]  
xa %>% dim
```

```
2500 33
```

```
In [10]: xb <- z.inputs[1:2500 + 2500]  
xb %>% dim
```

```
2500 33
```

Organize datasets.

```
In [11]: xy <- NULL
for (icol in 5:ncol(yy)) {
  y0 <- yy[, icol, with = FALSE][[1]]
  ya <- y0[1:n]
  yb <- y0[1:n + n]
  ybia <- matrix(y0[-(1:(2*n))], nrow = n, byrow = FALSE)
  for (i in 1:32) {
    xy <- rbind(
      xy
      , data.table(
        j = 1:n
        , i = rep(i, n)
        , l = rep(icol - 4)
        , xb = as.matrix(xa[, i + 1, with=FALSE])[,1]
        , xa = as.matrix(xb[, i + 1, with=FALSE])[,1]
        , yb = ya
        , ya = yb
        , yaib = ybia[, i]
      )
    )
  }
}
xy %>% summary
```

j	i	l	xb
Min. : 1.0	Min. : 1.00	Min. : 1	Min. : 0.000e+00
1st Qu.: 625.8	1st Qu.: 8.75	1st Qu.: 13	1st Qu.: 1.000e+00
Median : 1250.5	Median : 16.50	Median : 25	Median : 6.000e+00
Mean : 1250.5	Mean : 16.50	Mean : 25	Mean : 3.121e+07
3rd Qu.: 1875.2	3rd Qu.: 24.25	3rd Qu.: 37	3rd Qu.: 6.092e+03
Max. : 2500.0	Max. : 32.00	Max. : 49	Max. : 1.321e+09
xa	yb	ya	
Min. : 0.000e+00	Min. : -6.433e+09	Min. : -2.059e+10	
1st Qu.: 1.000e+00	1st Qu.: 0.000e+00	1st Qu.: 0.000e+00	
Median : 6.000e+00	Median : 0.000e+00	Median : 0.000e+00	
Mean : 3.120e+07	Mean : 9.967e+09	Mean : 1.005e+10	
3rd Qu.: 6.092e+03	3rd Qu.: 1.100e+01	3rd Qu.: 1.100e+01	
Max. : 1.320e+09	Max. : 1.066e+13	Max. : 1.151e+13	
yaib			
Min. : -3.088e+10			
1st Qu.: 0.000e+00			
Median : 0.000e+00			
Mean : 1.004e+10			
3rd Qu.: 1.100e+01			
Max. : 1.272e+13			

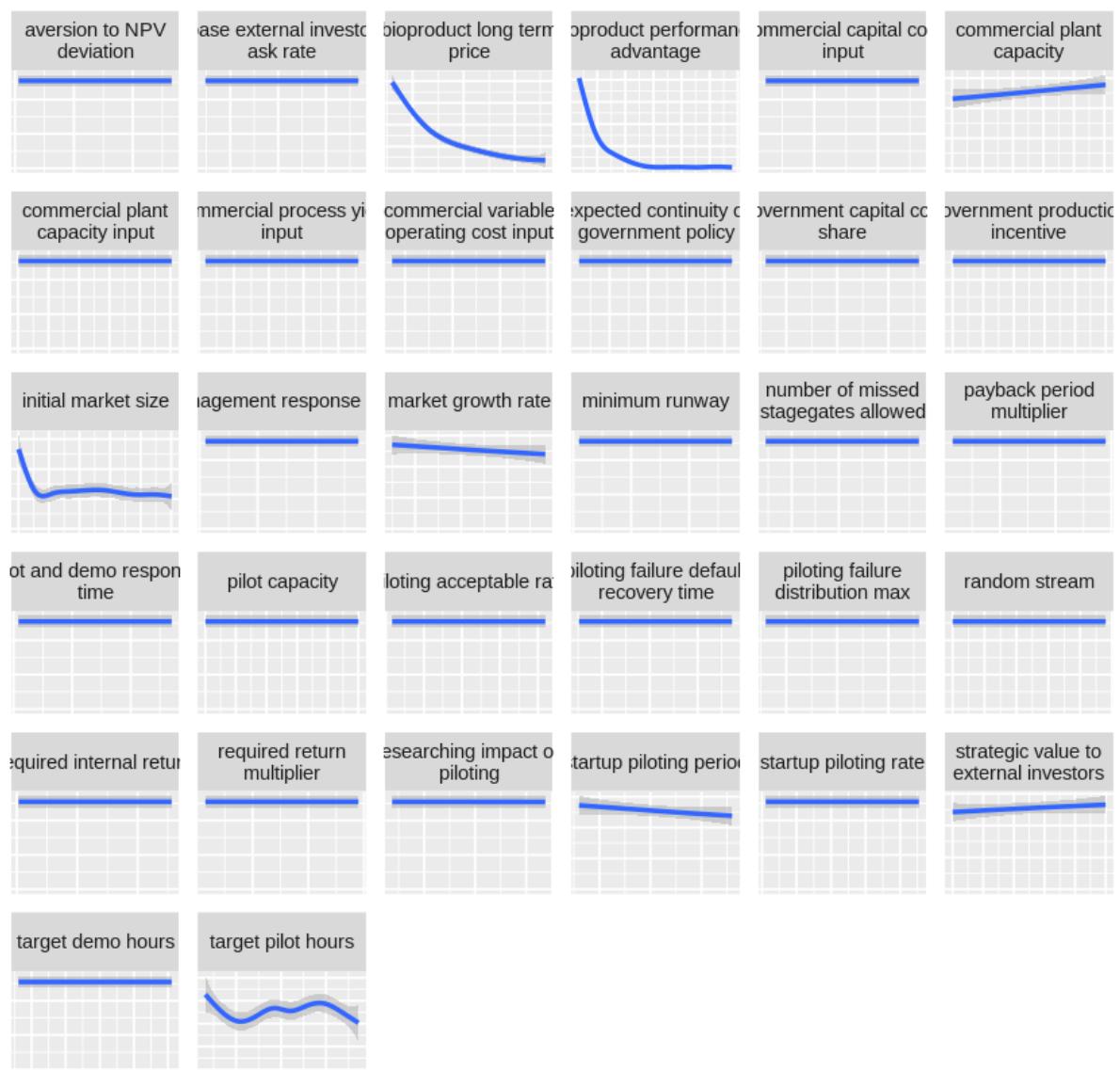
Trends in output.

```
In [12]: xy1 <- rbind(
  xy[, .(x = xa, y = ya), by = .(j, i, l)]
, xy[, .(x = xb, y = yb), by = .(j, i, l)]
)[
, .(
  Input = colnames(z.inputs)[1+i]
, Output = colnames(z.outputs)[4+l]
, x
, y
)
]
for (outname in xy1[, unique(Output)]) {
g <- ggplot(
  xy1[Output == outname]
, aes(x = x, y = y)
) +
  geom_smooth(method = "gam", formula = y ~ s(x, bs = "cs")) +
  scale_y_continuous(limits = c(0, NA)) +
  facet_wrap(. ~ Input, scales = "free", labeller = label_wrap_gen())
+
  ggtitle(paste("Conditioned Output for", outname)) +
  theme(
    axis.title.x =element_blank()
, axis.text.x =element_blank()
, axis.ticks.x =element_blank()
, axis.title.y =element_blank()
, axis.text.y =element_blank()
, axis.ticks.y =element_blank()
)
  print(g)
}
```

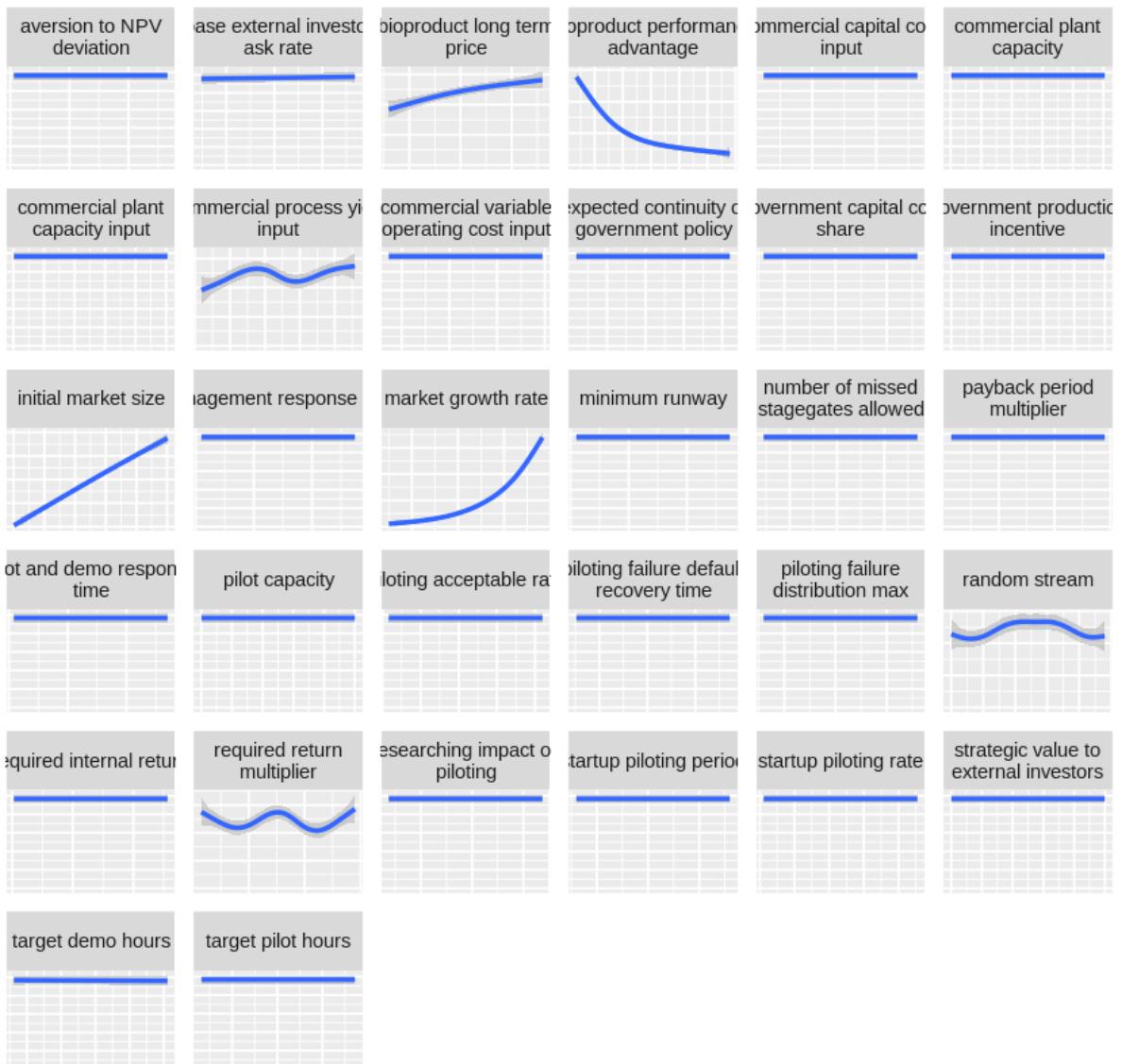
Warning message:

"Removed 32 rows containing non-finite values (stat_smooth)."

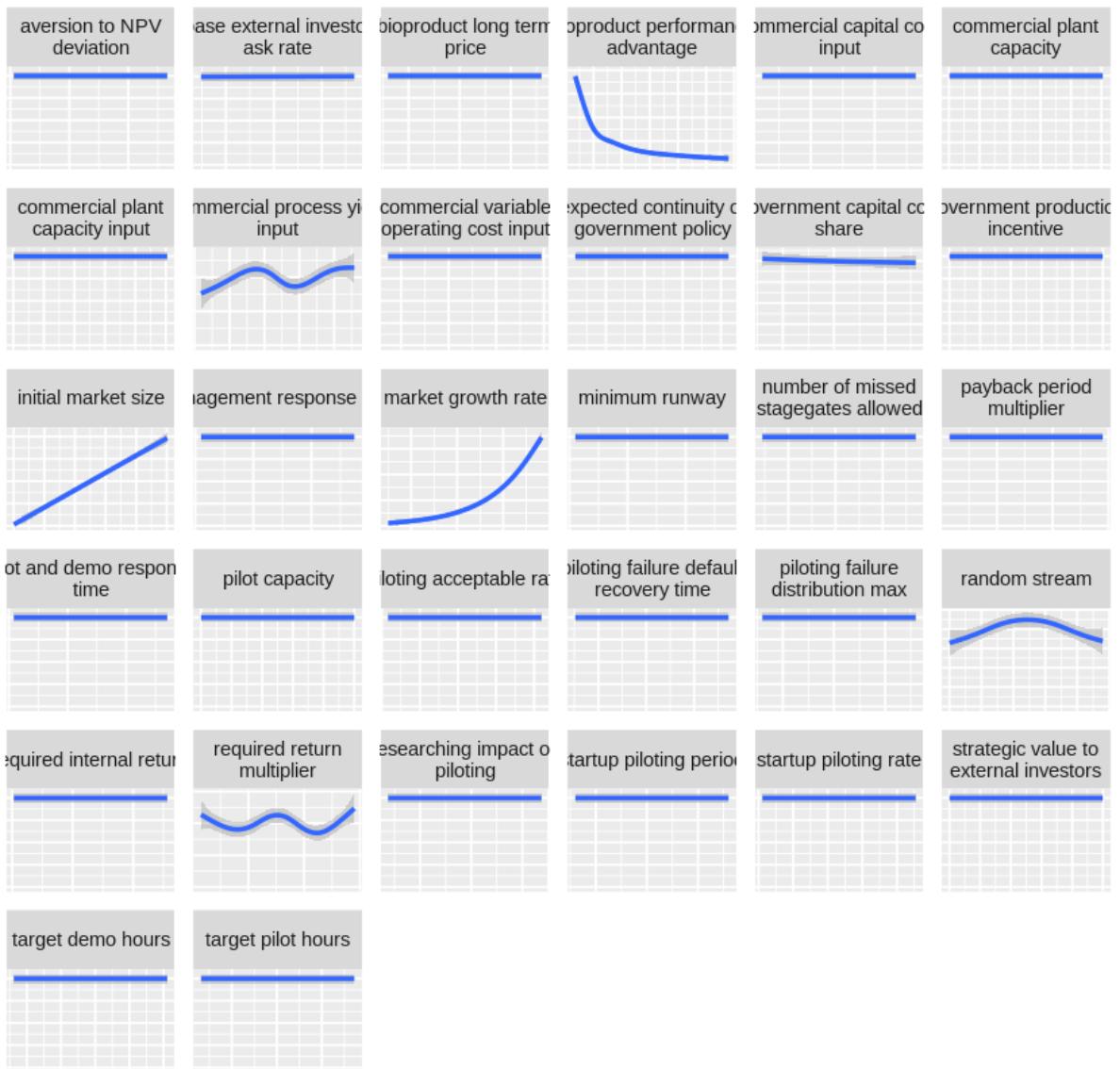
Conditioned Output for bioproduct market share mass



Conditioned Output for current market size economic



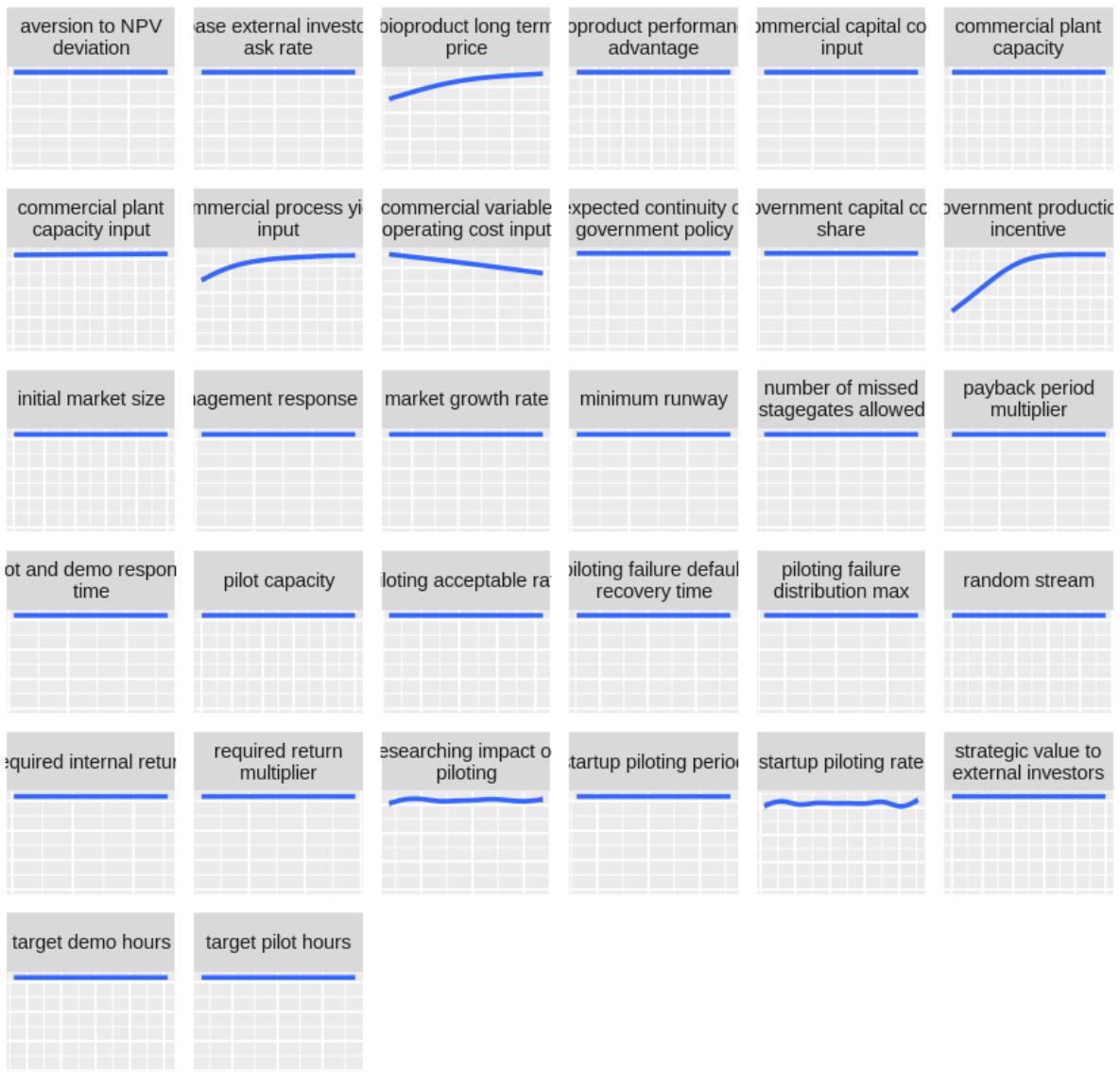
Conditioned Output for current market size mass



Warning message:

"Removed 38 rows containing missing values (geom_smooth)."

Conditioned Output for long term market share

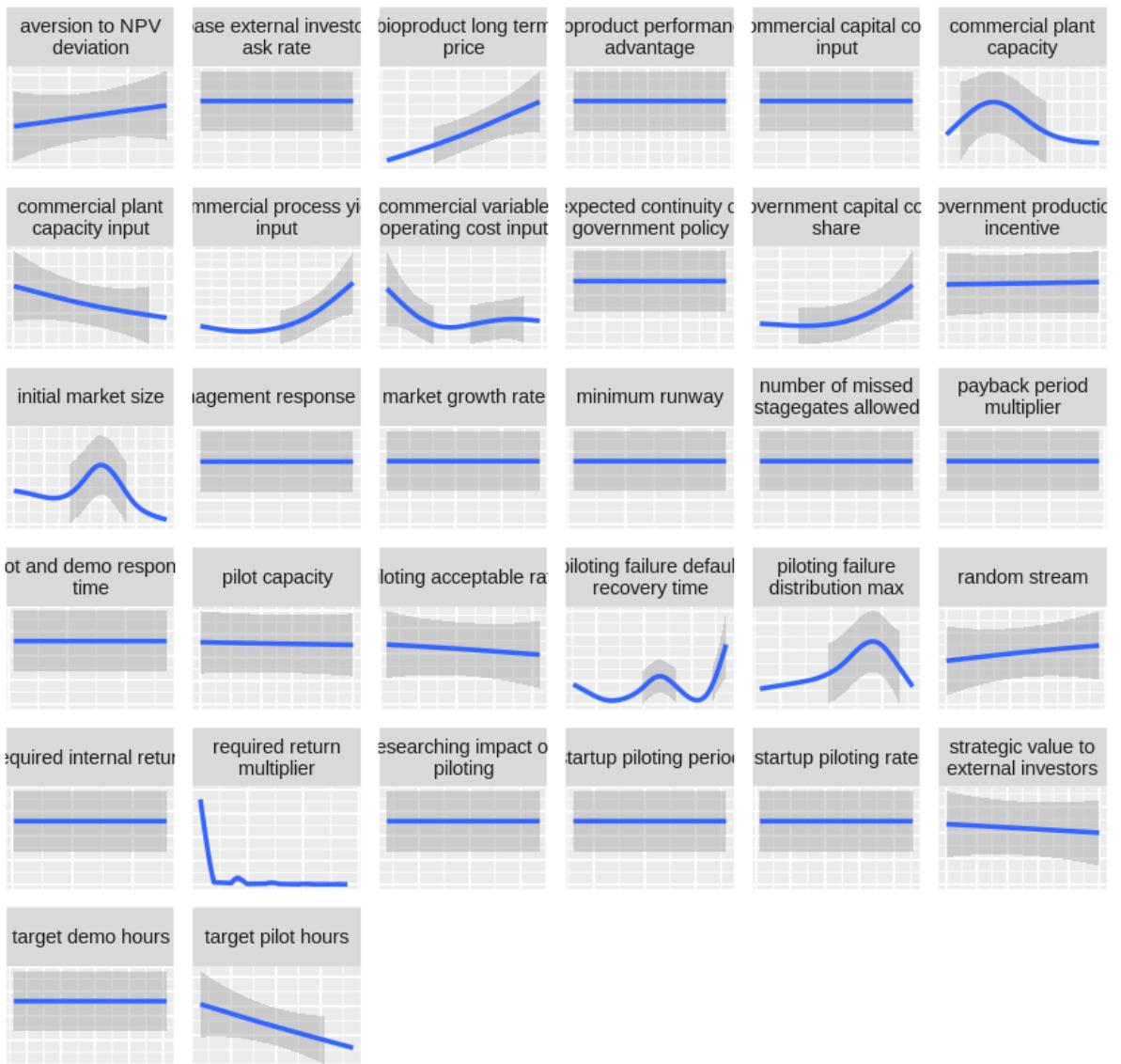


Warning message:

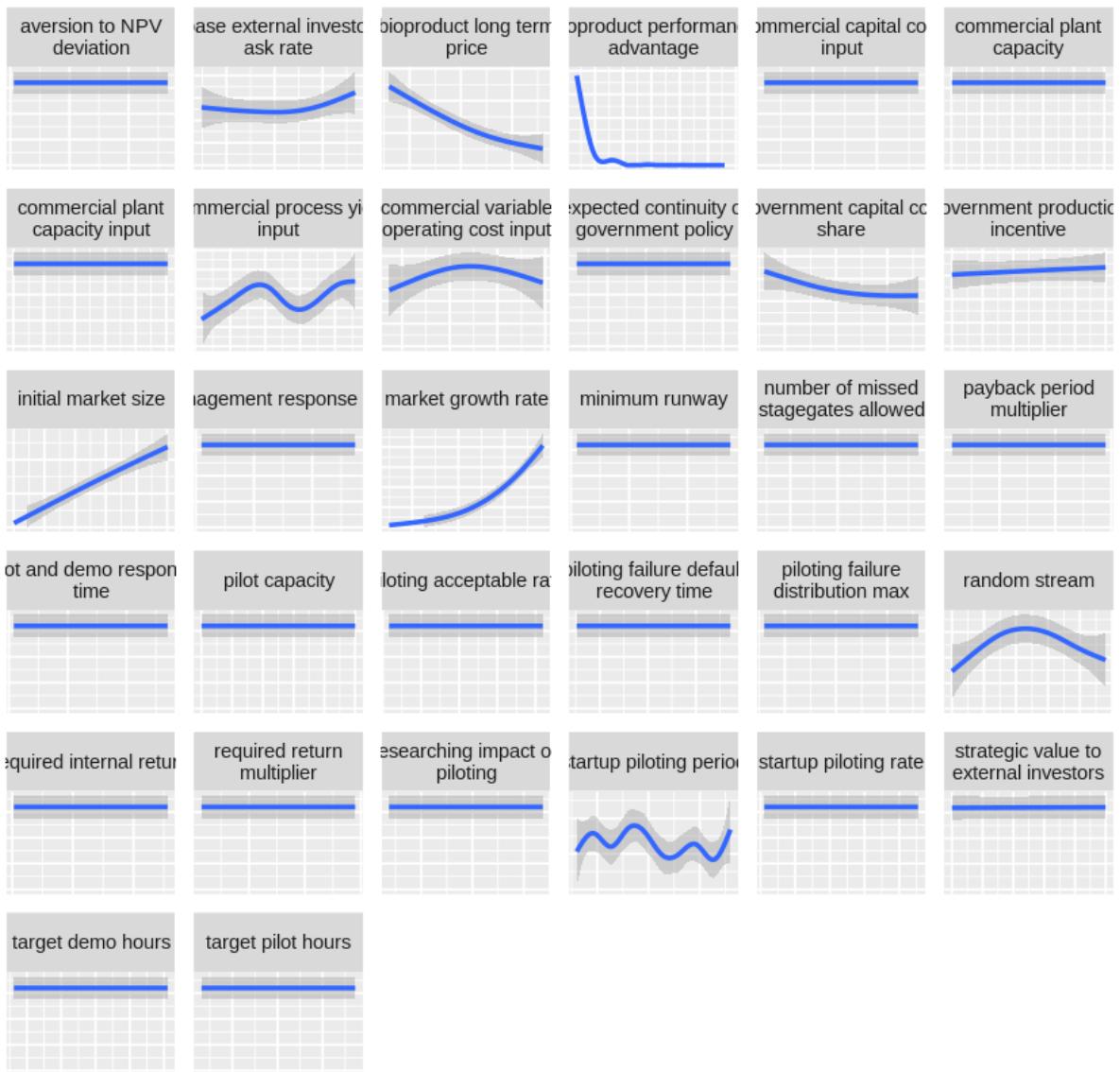
"Removed 32 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 26 rows containing missing values (geom_smooth)."

Conditioned Output for long term market value



Conditioned Output for Adopters

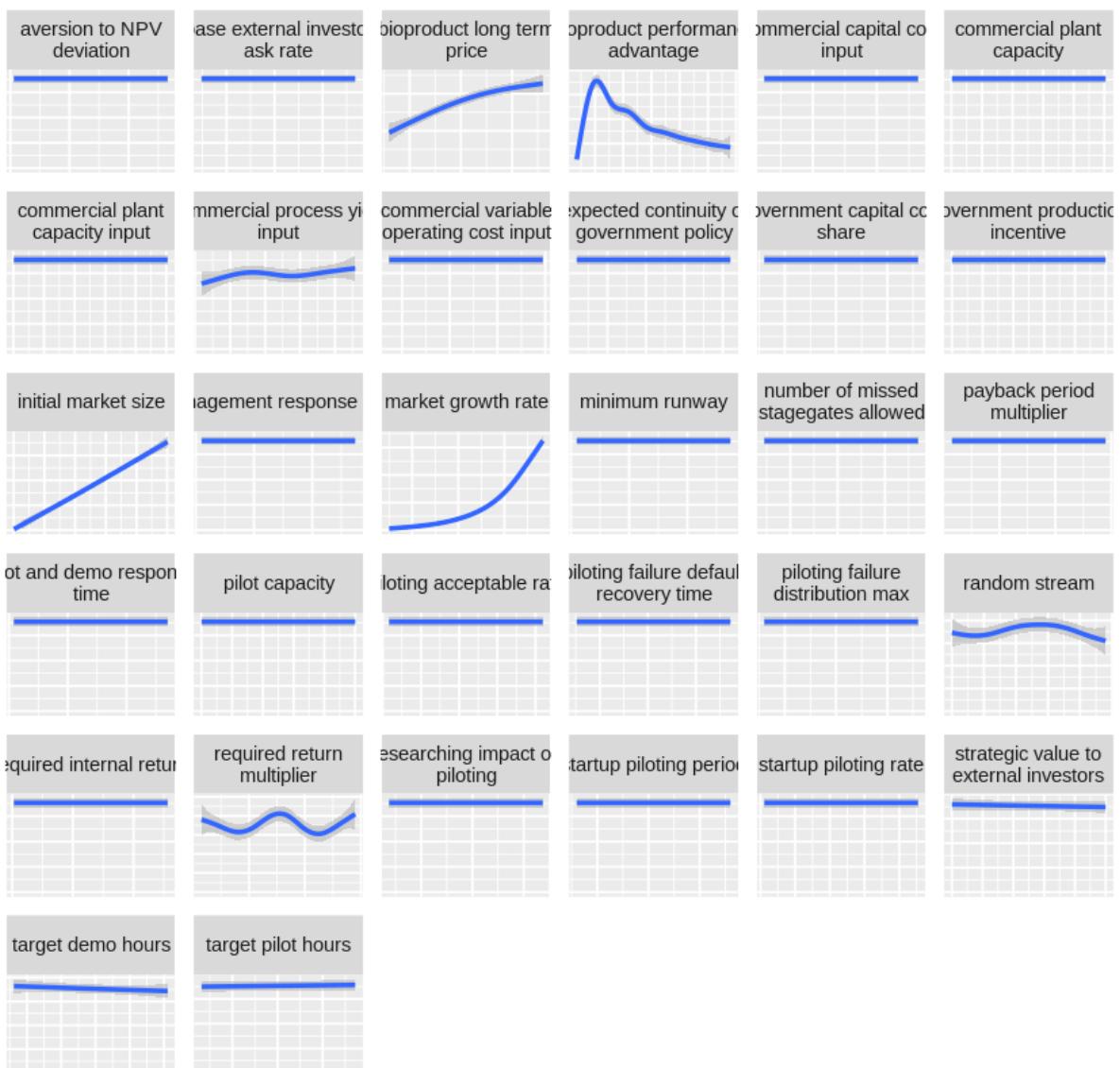


Warning message:

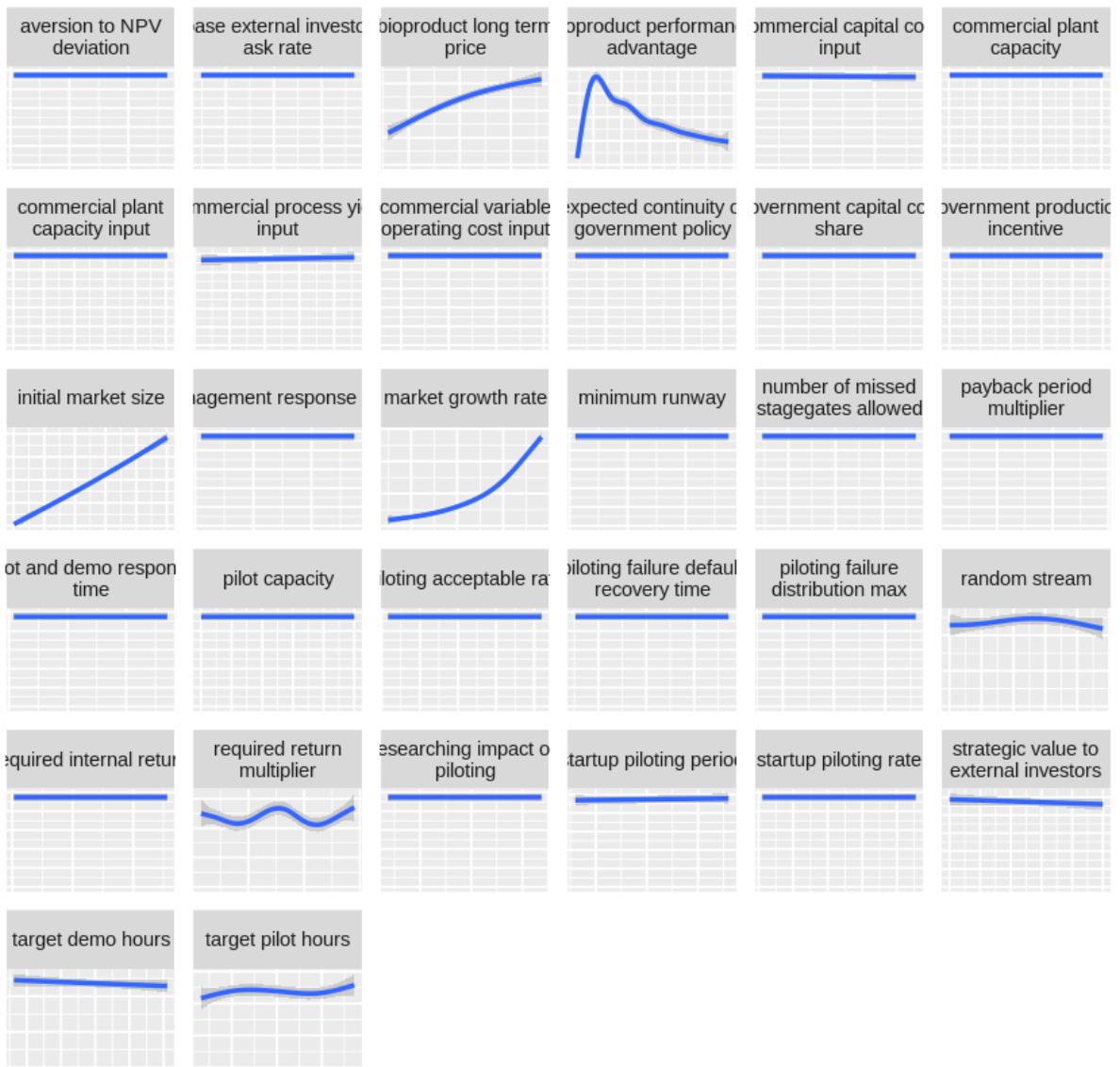
"Removed 416 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 1 rows containing missing values (geom_smooth)."

Conditioned Output for NonAdopters



Conditioned Output for Potential Adopters



Warning message:

"Removed 7 rows containing missing values (geom_smooth)."

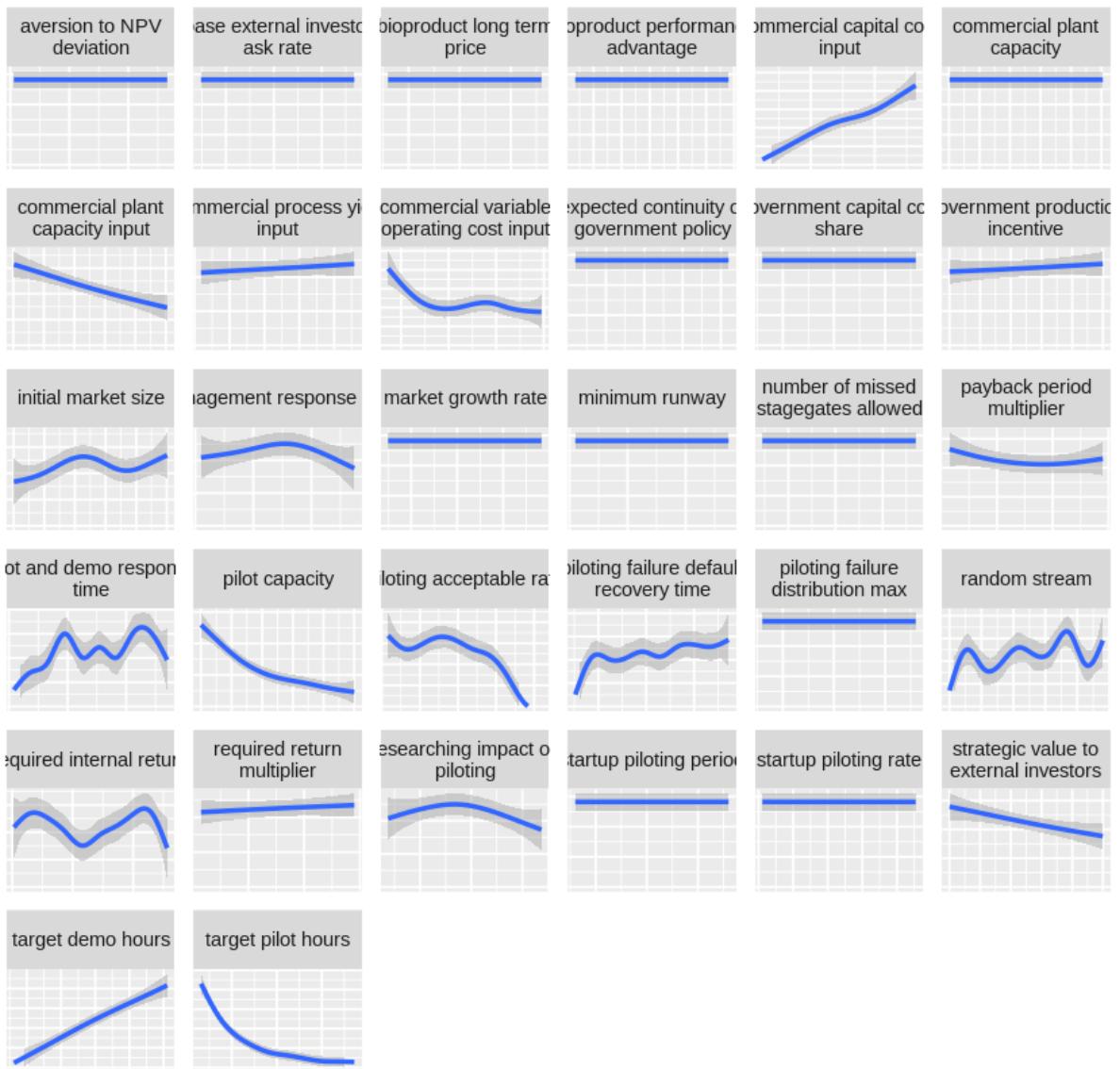
Conditioned Output for abandoning bioproduct



Warning message:

"Removed 5 rows containing missing values (geom_smooth)."

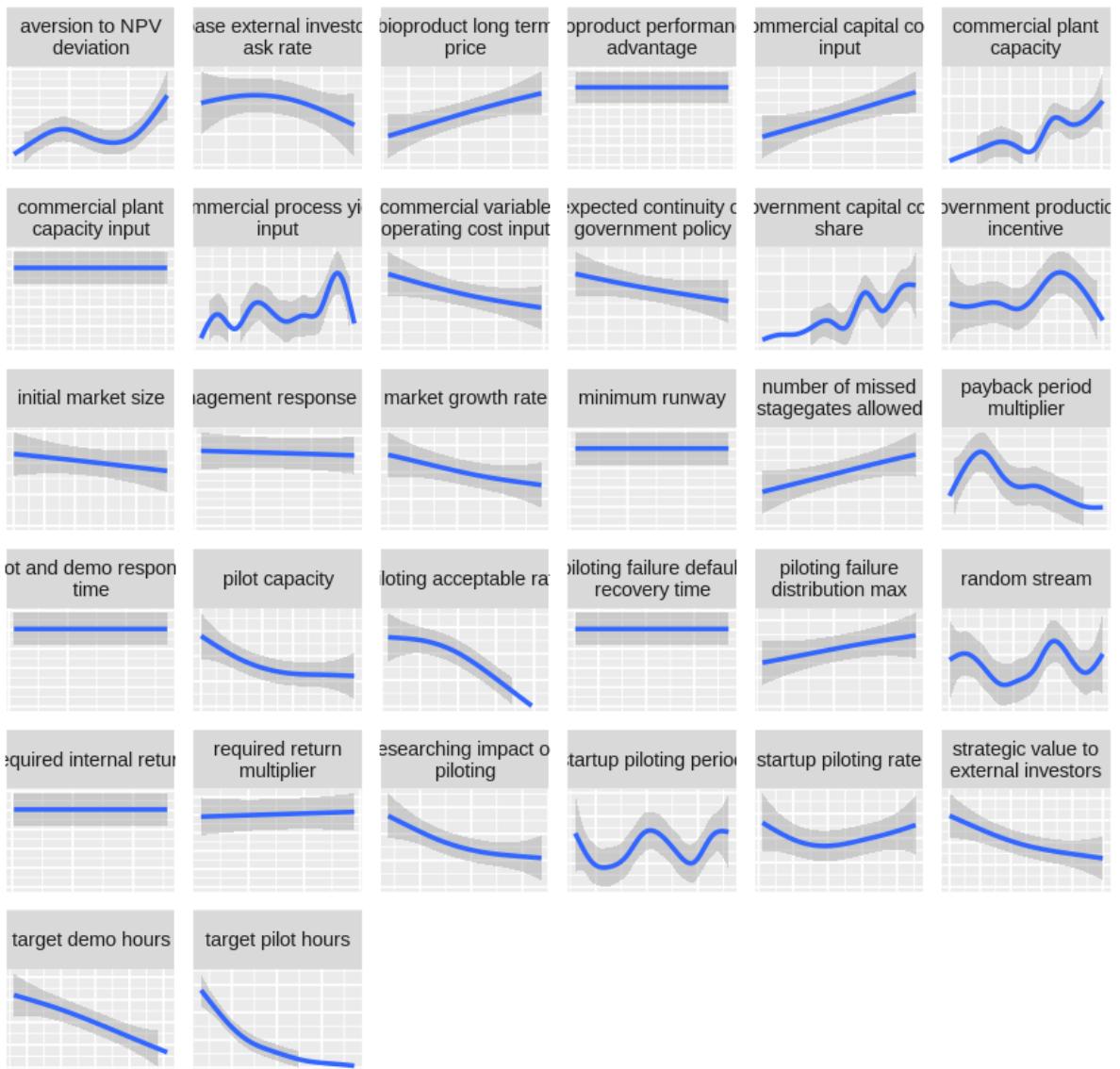
Conditioned Output for Cumulative Demoing Production



Warning message:

"Removed 10 rows containing missing values (geom_smooth)."

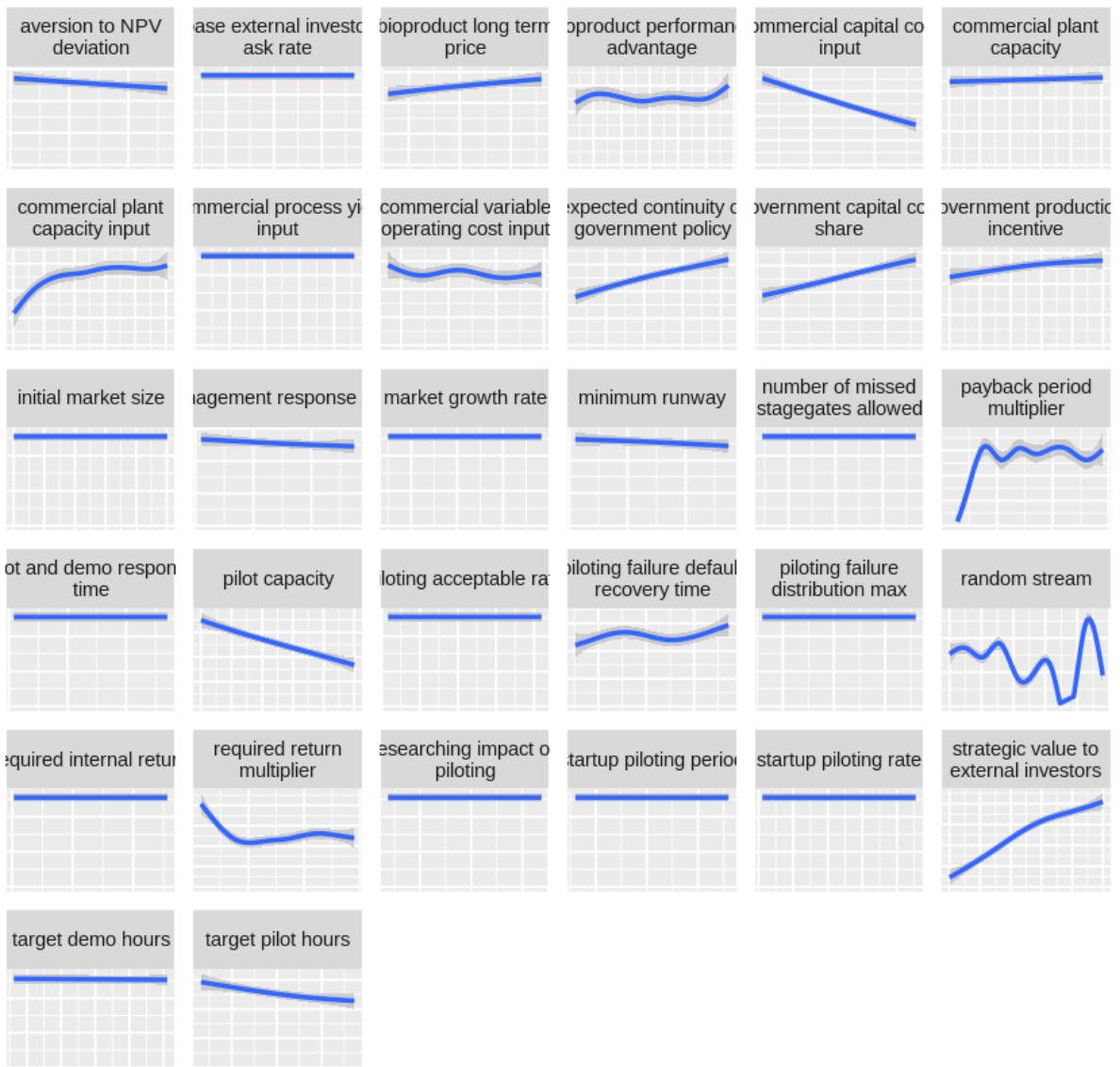
Conditioned Output for Cumulative Production



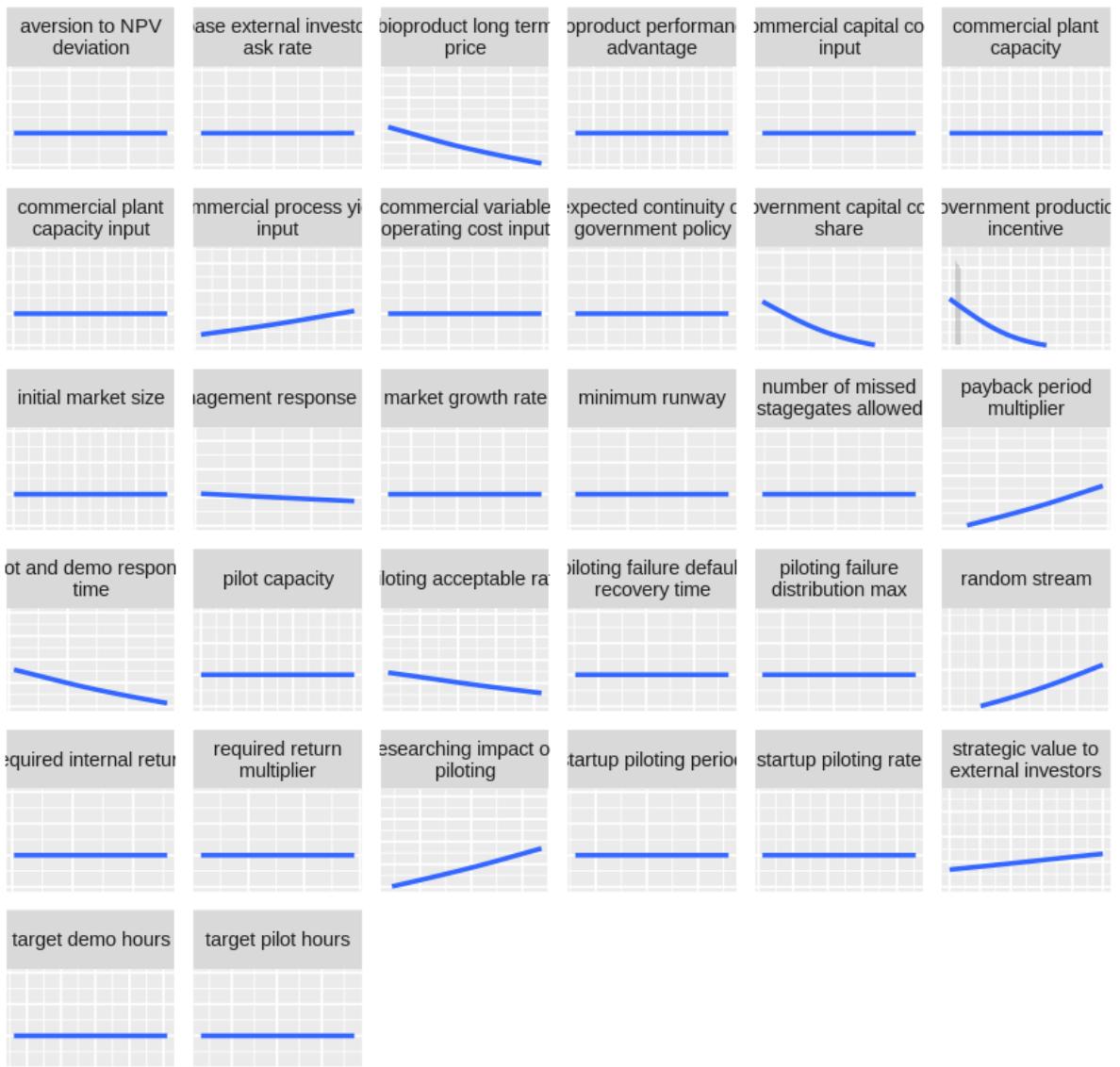
Warning message:

"Removed 77 rows containing missing values (geom_smooth)."

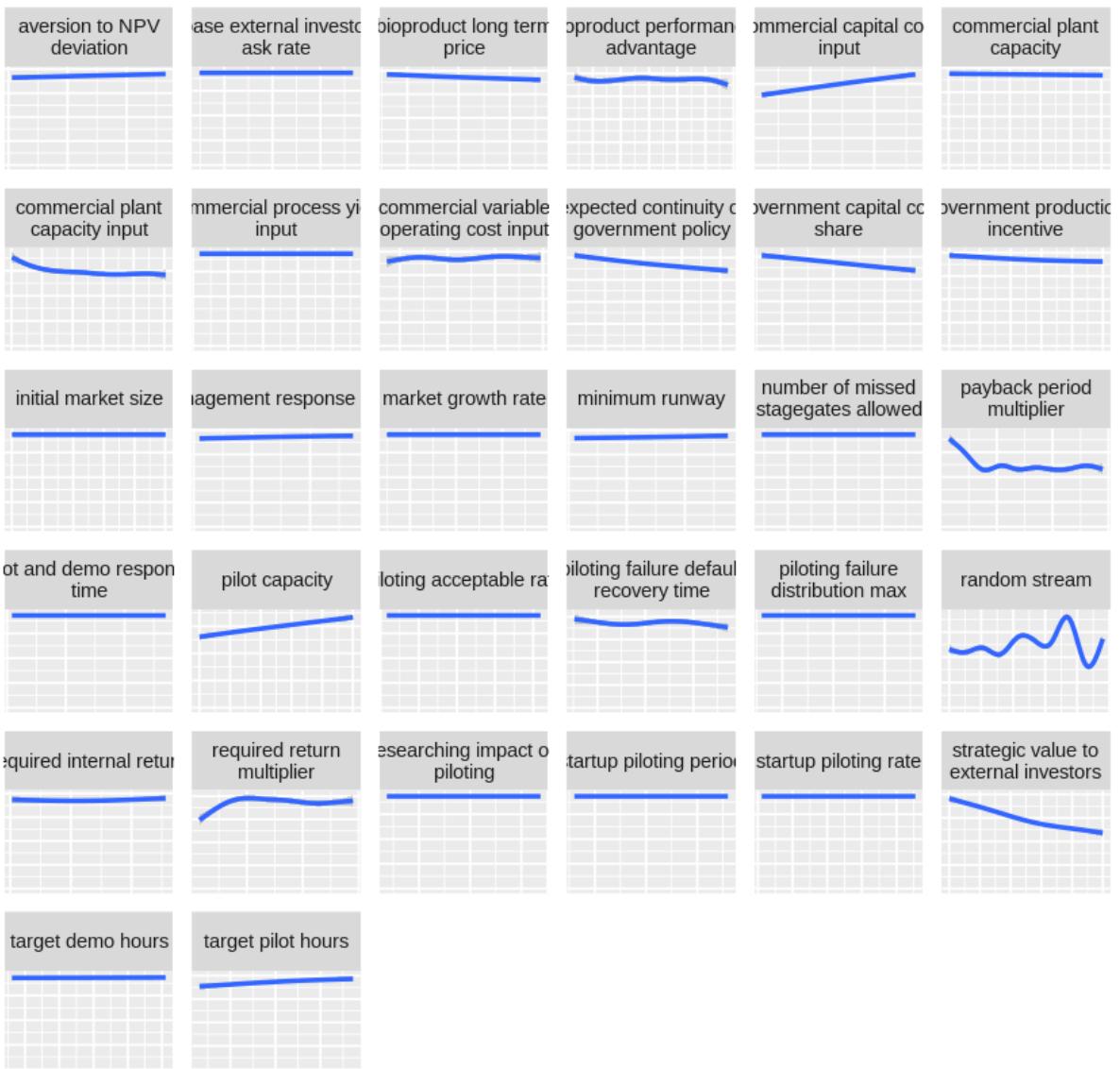
Conditioned Output for prepiloting



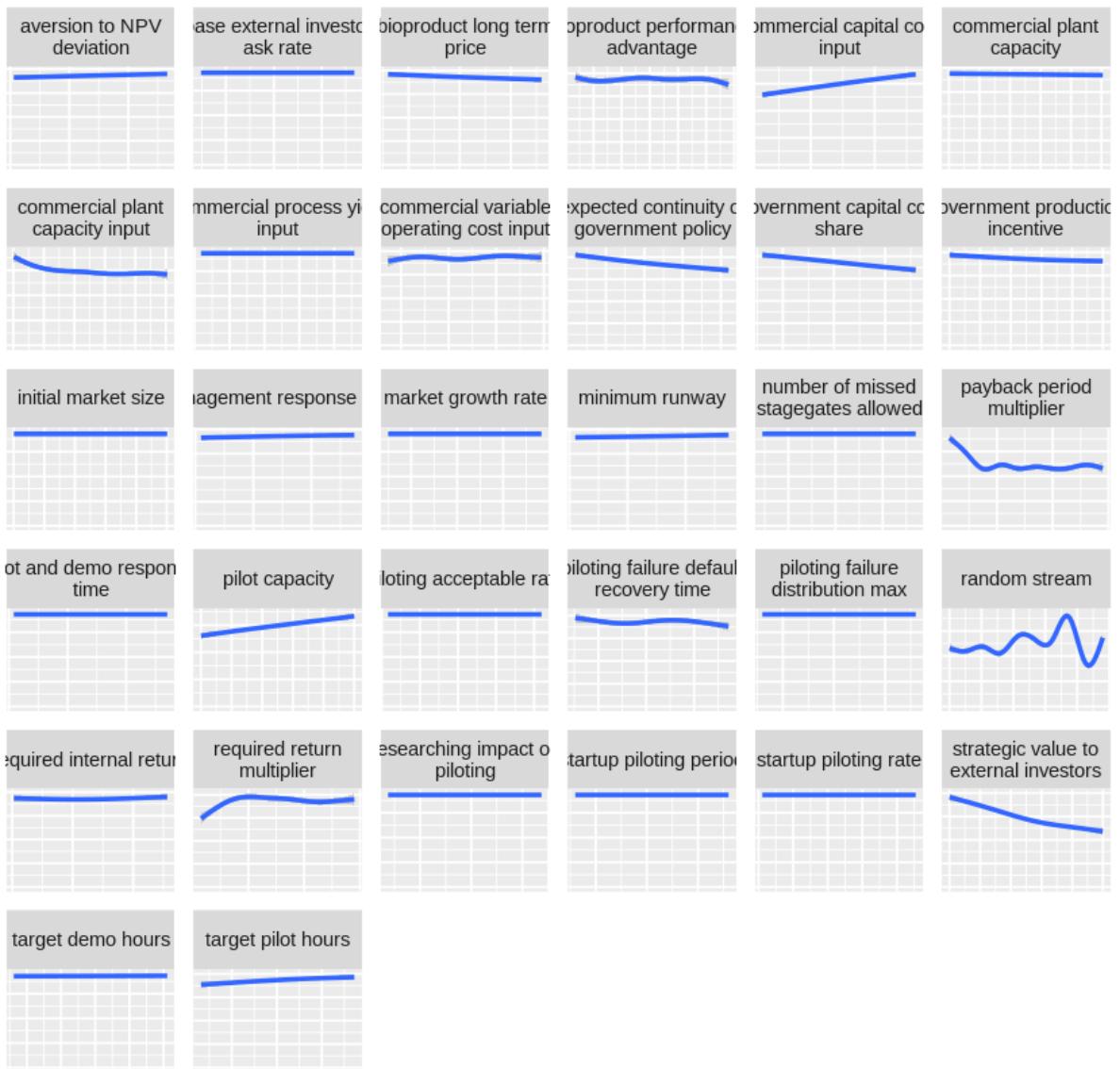
Conditioned Output for pilot plant construction



Conditioned Output for pilot plant is built



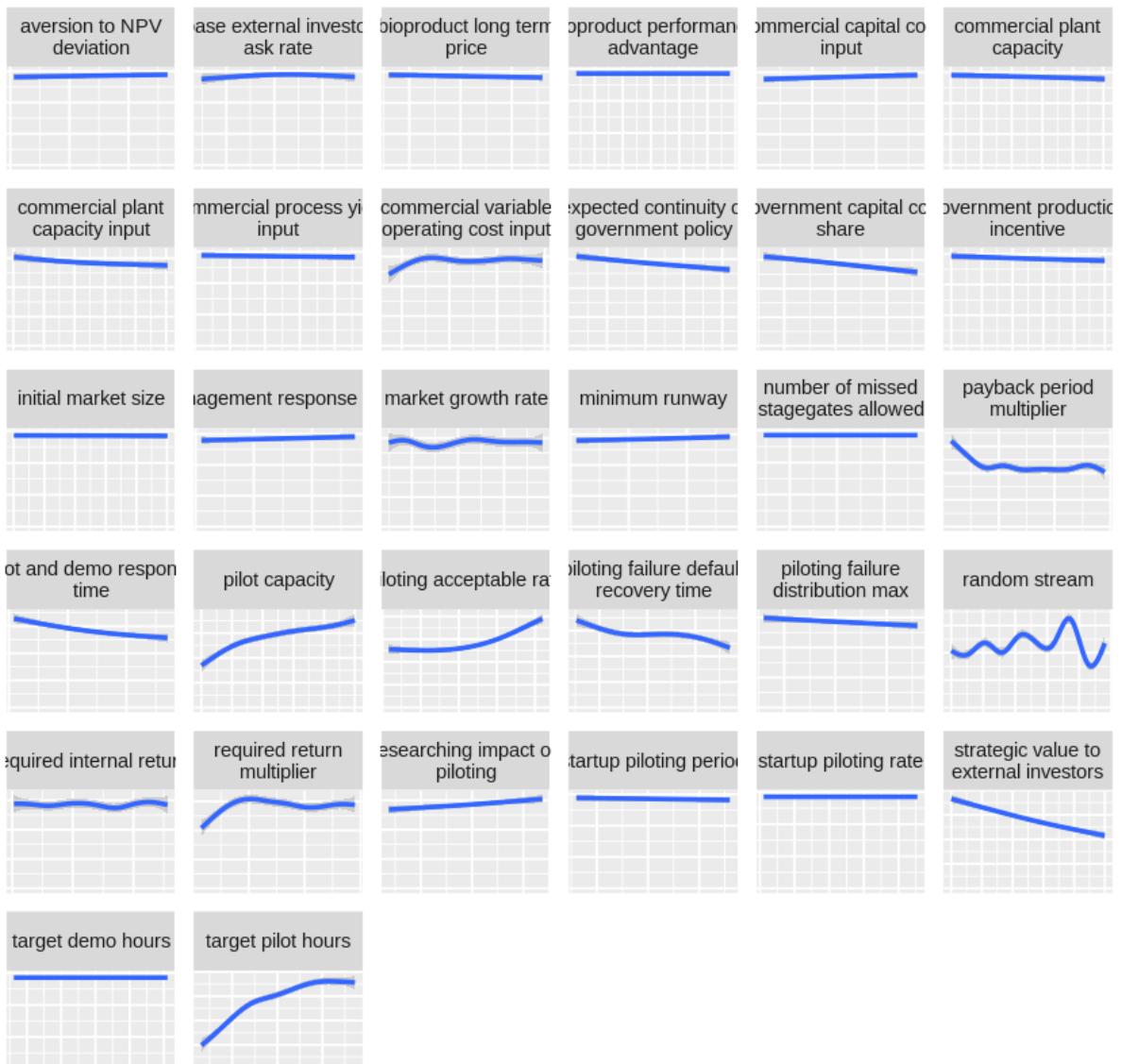
Conditioned Output for startup piloting complete



Warning message:

"Removed 8 rows containing missing values (geom_smooth)."

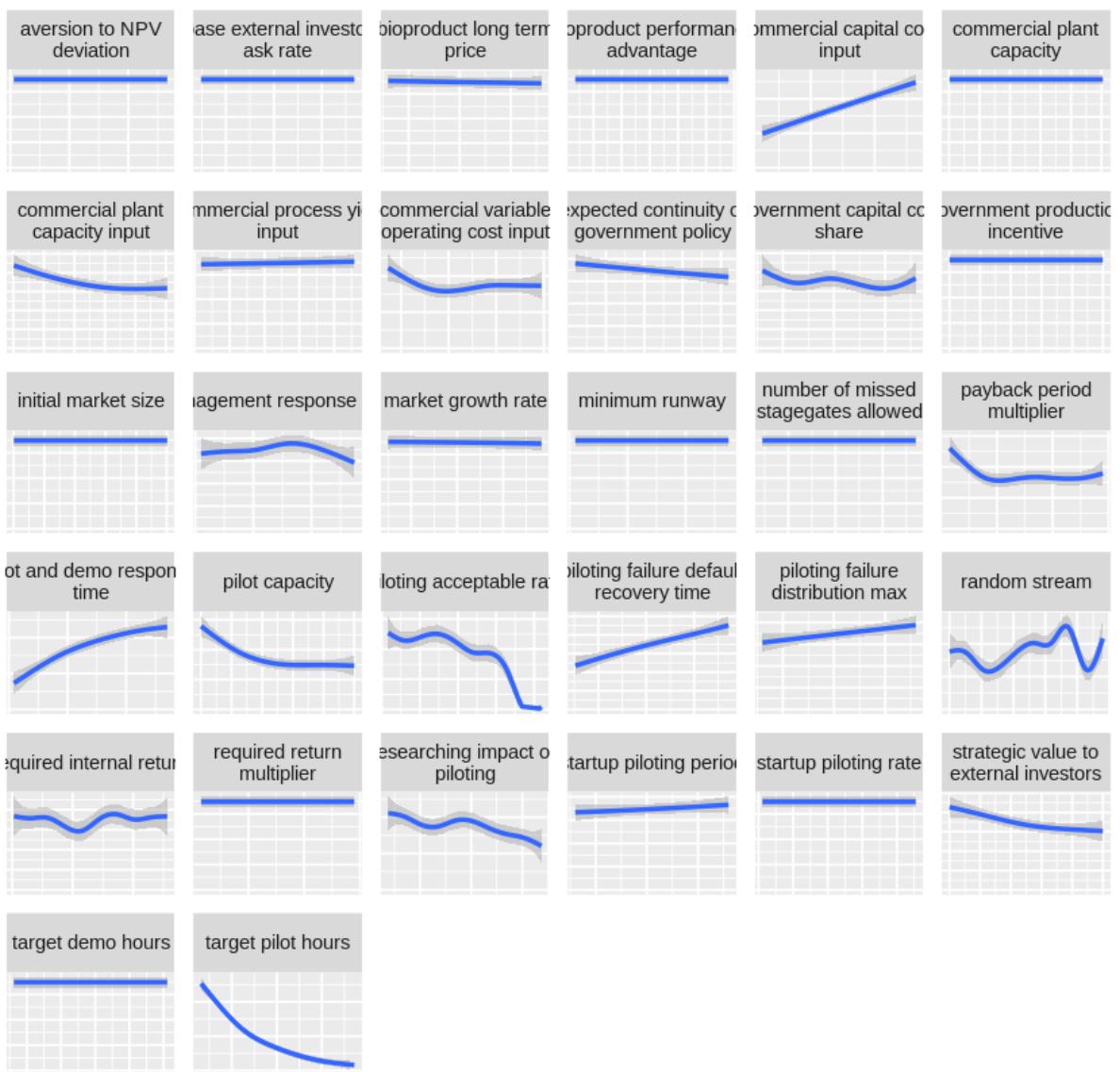
Conditioned Output for piloting ongoing



Warning message:

"Removed 8 rows containing missing values (geom_smooth)."

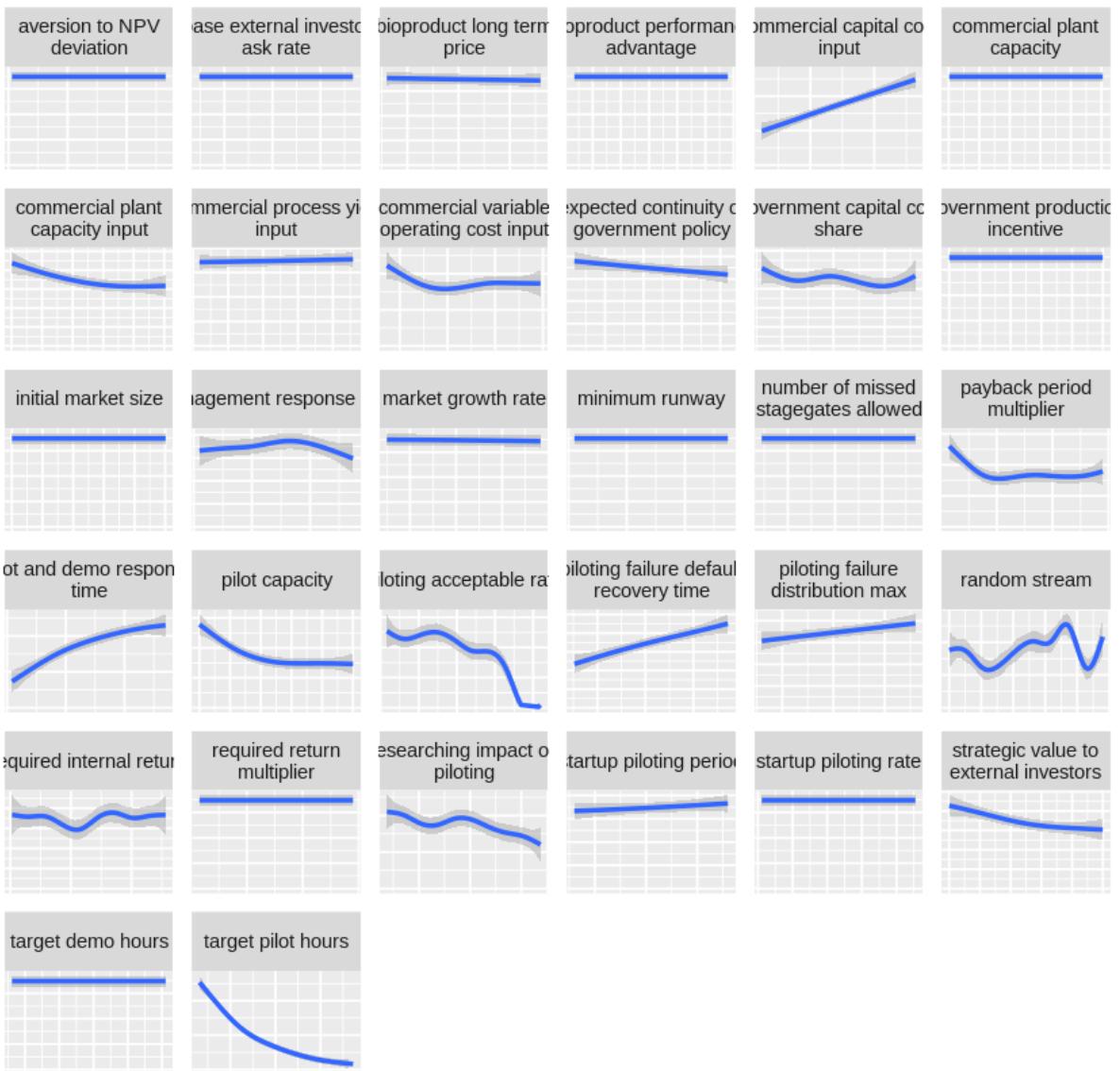
Conditioned Output for piloting progress



Warning message:

"Removed 5 rows containing missing values (geom_smooth)."

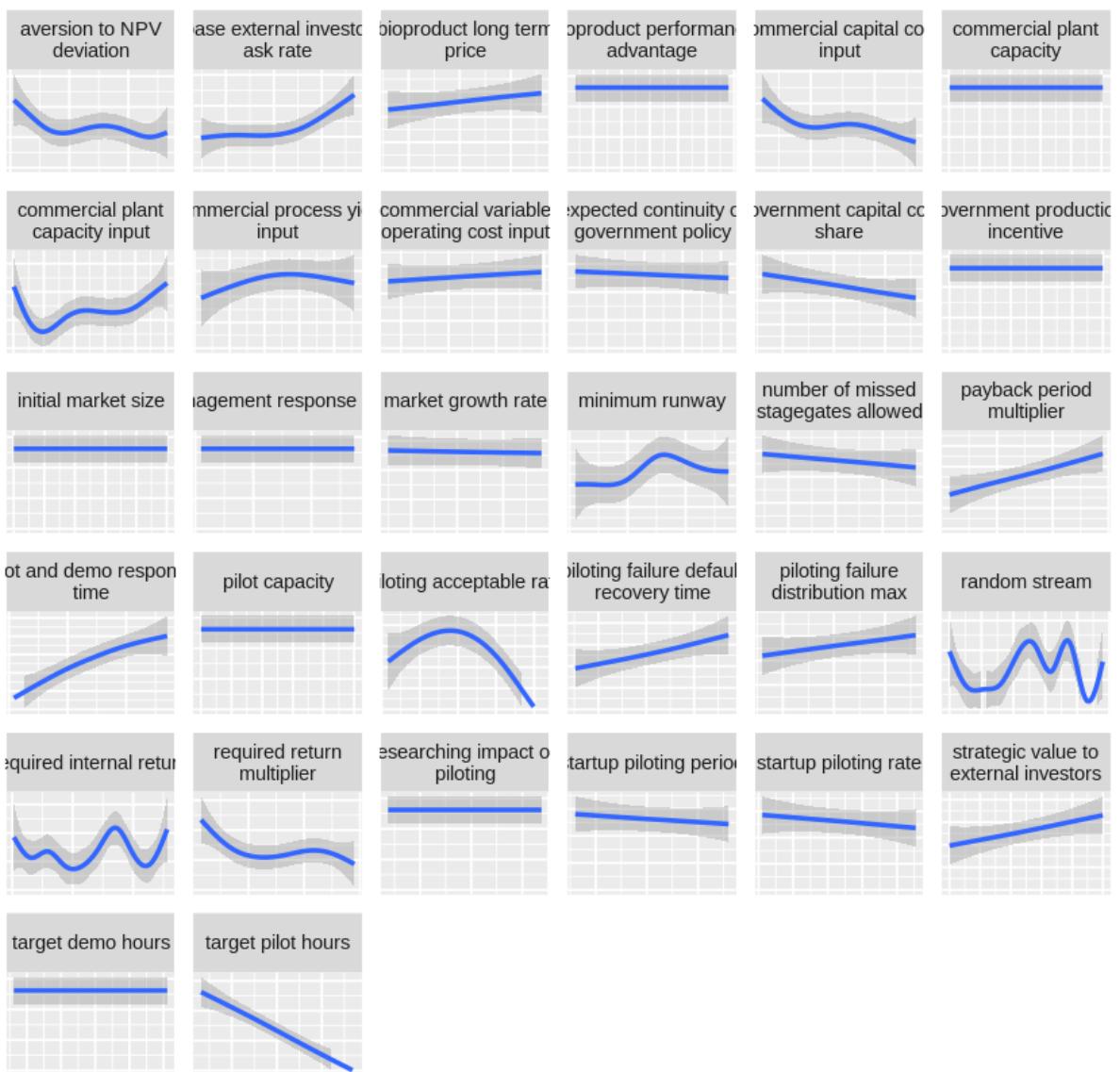
Conditioned Output for piloting complete



Warning message:

"Removed 86 rows containing missing values (geom_smooth)."

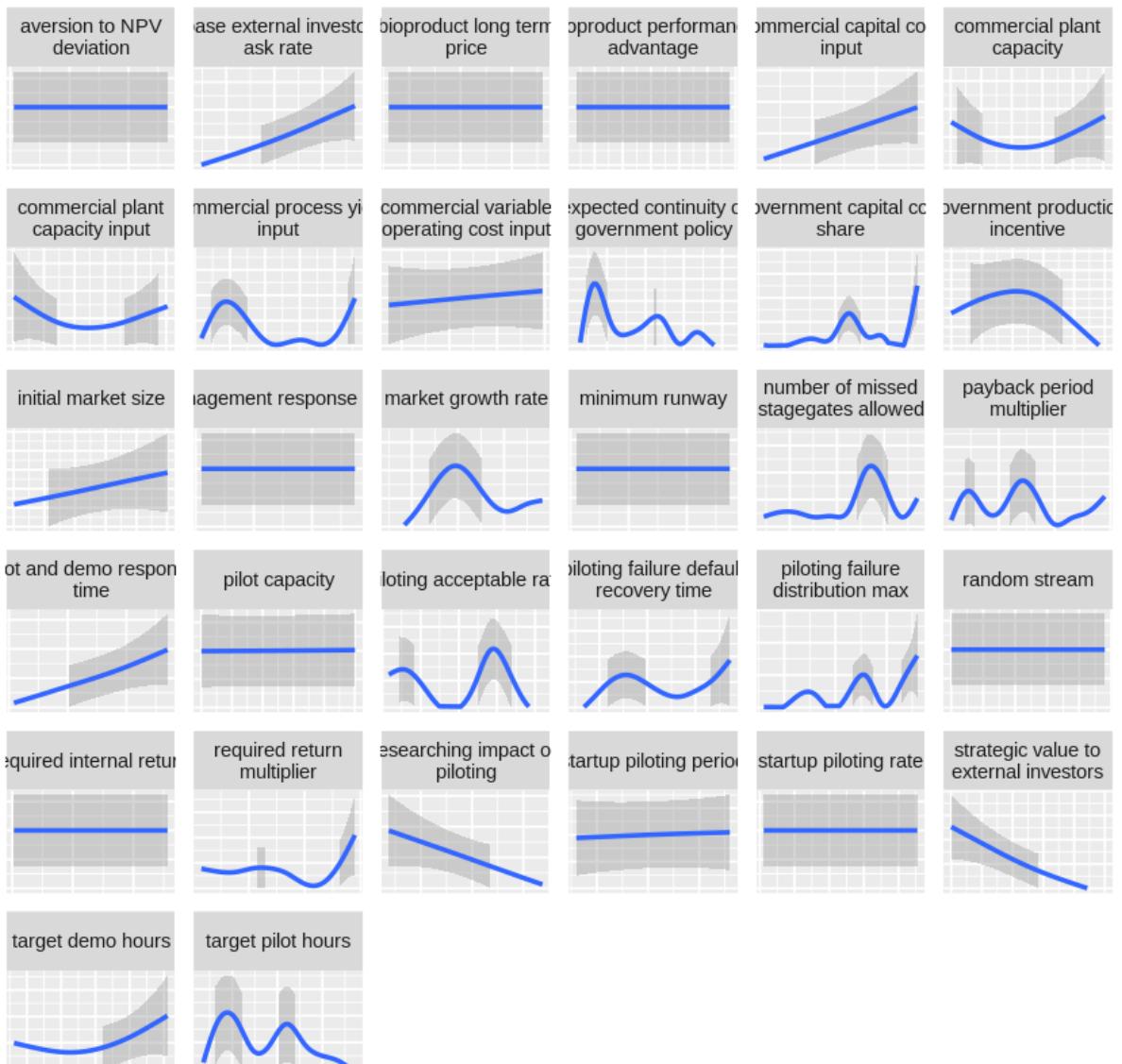
Conditioned Output for predemoing



Warning message:

"Removed 7 rows containing missing values (geom_smooth)."

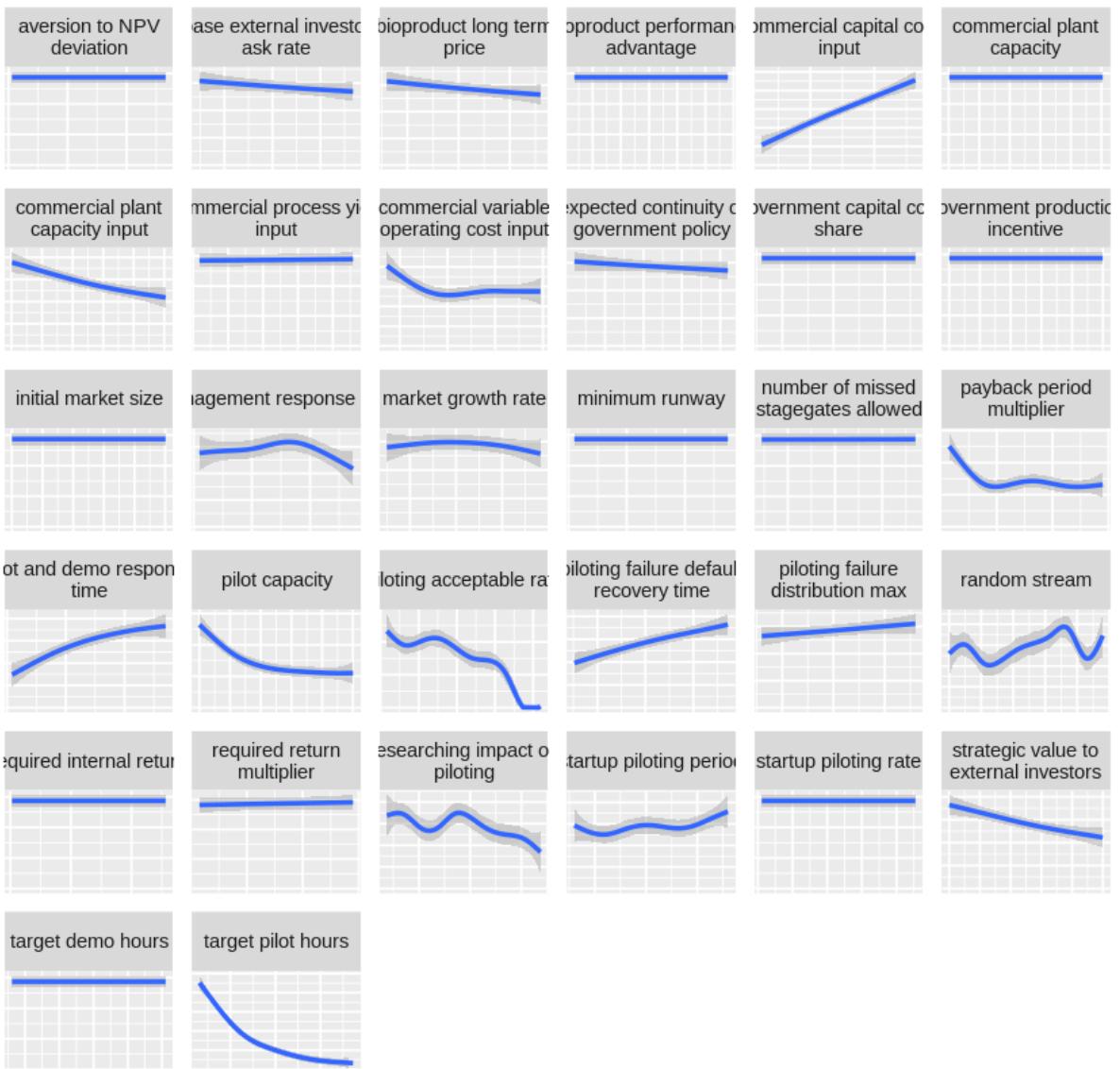
Conditioned Output for demo plant construction



Warning message:

"Removed 11 rows containing missing values (geom_smooth)."

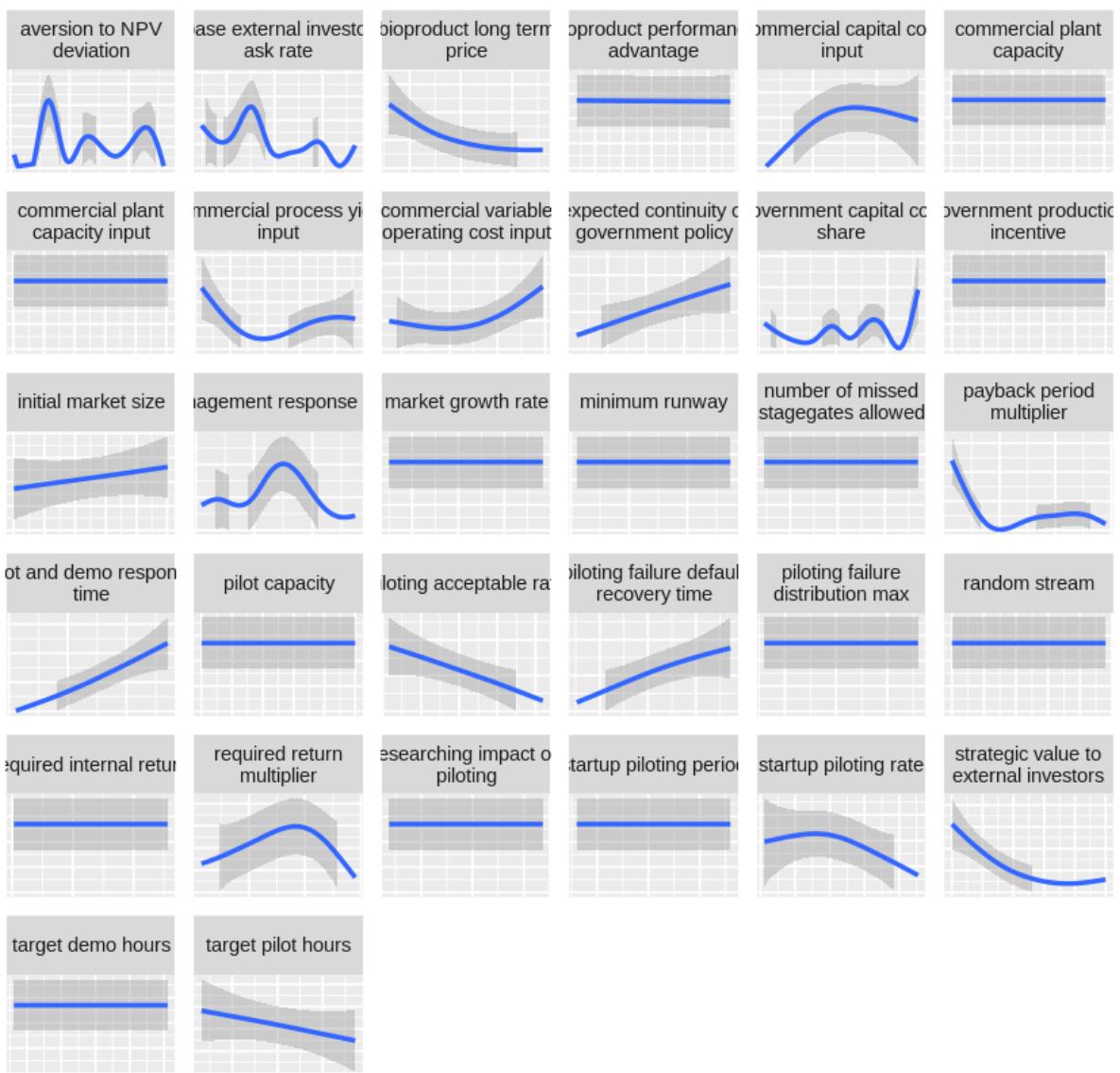
Conditioned Output for demo plant is built



Warning message:

"Removed 9 rows containing missing values (geom_smooth)."

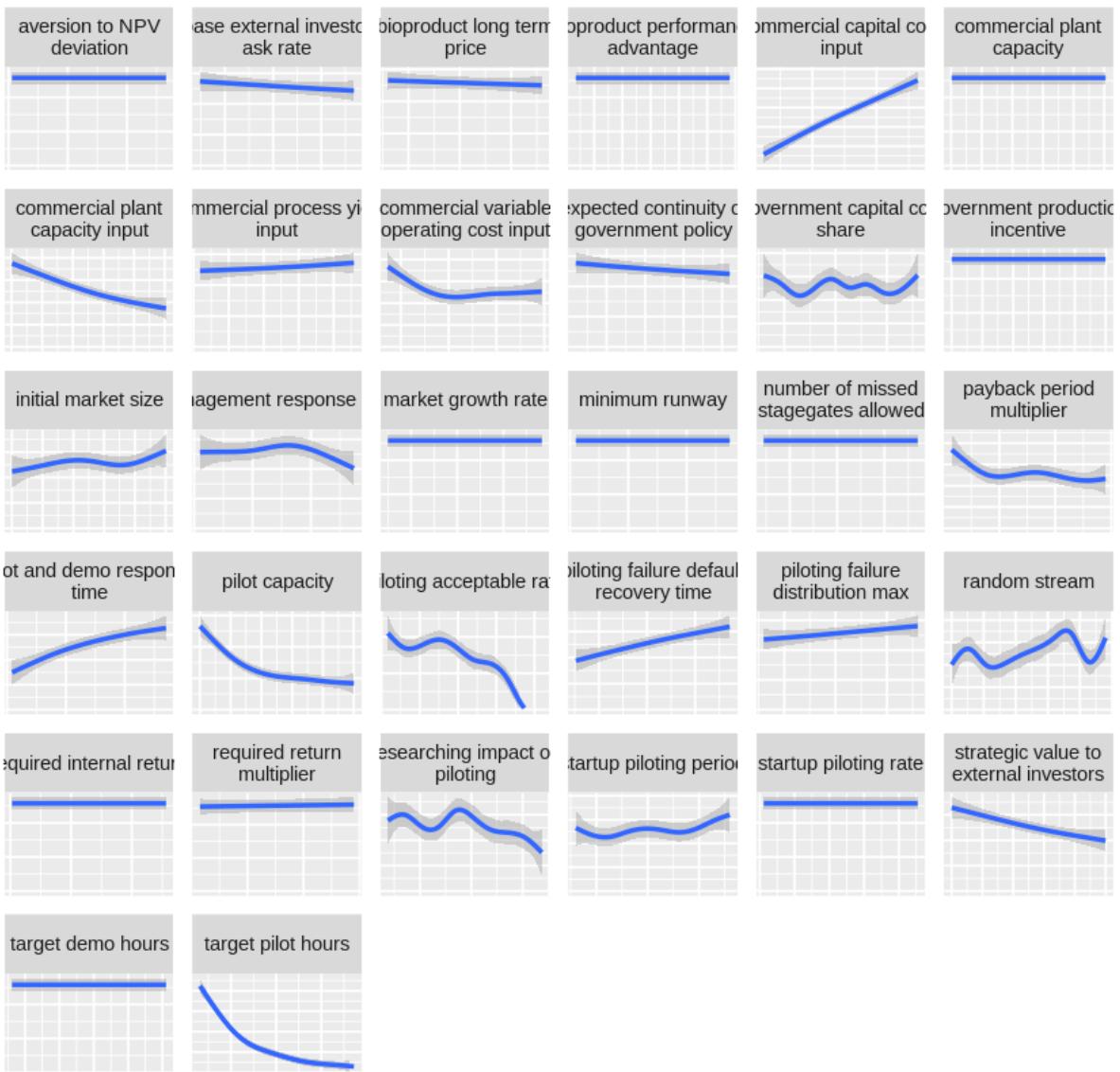
Conditioned Output for regulatory process ongoing



Warning message:

"Removed 4 rows containing missing values (geom_smooth)."

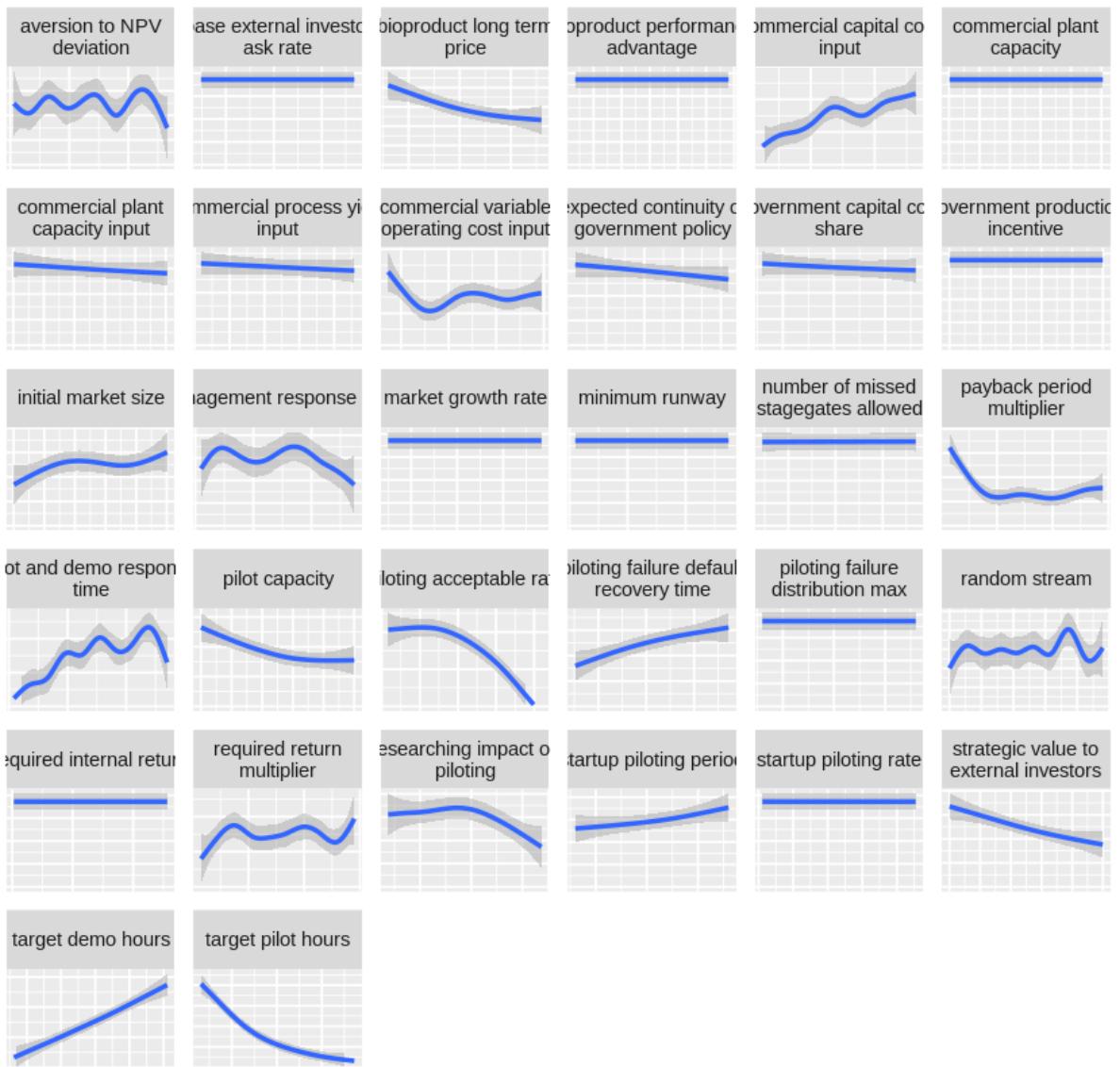
Conditioned Output for startup demoing completed



Warning message:

"Removed 7 rows containing missing values (geom_smooth)."

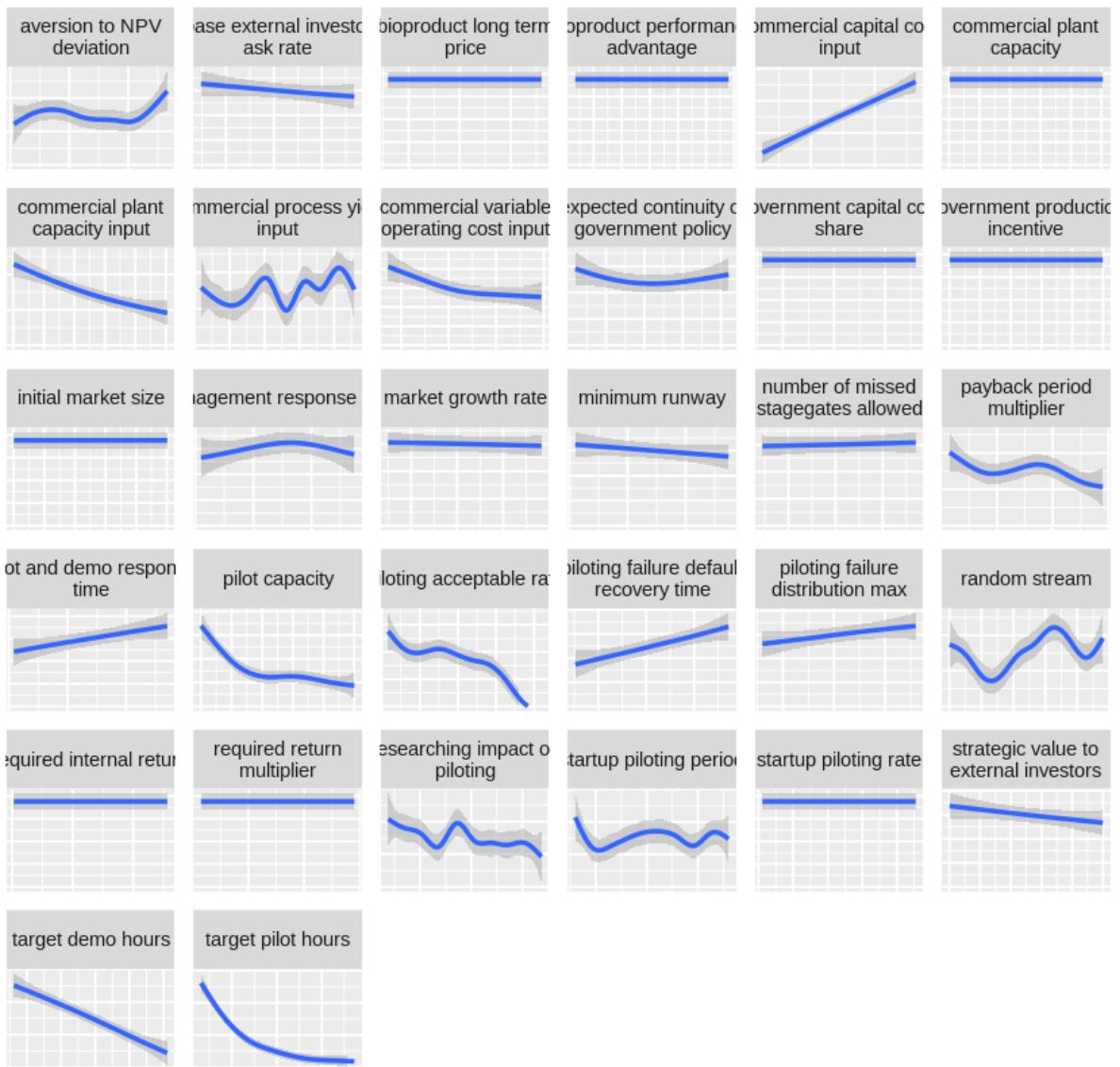
Conditioned Output for demoing ongoing



Warning message:

"Removed 5 rows containing missing values (geom_smooth)."

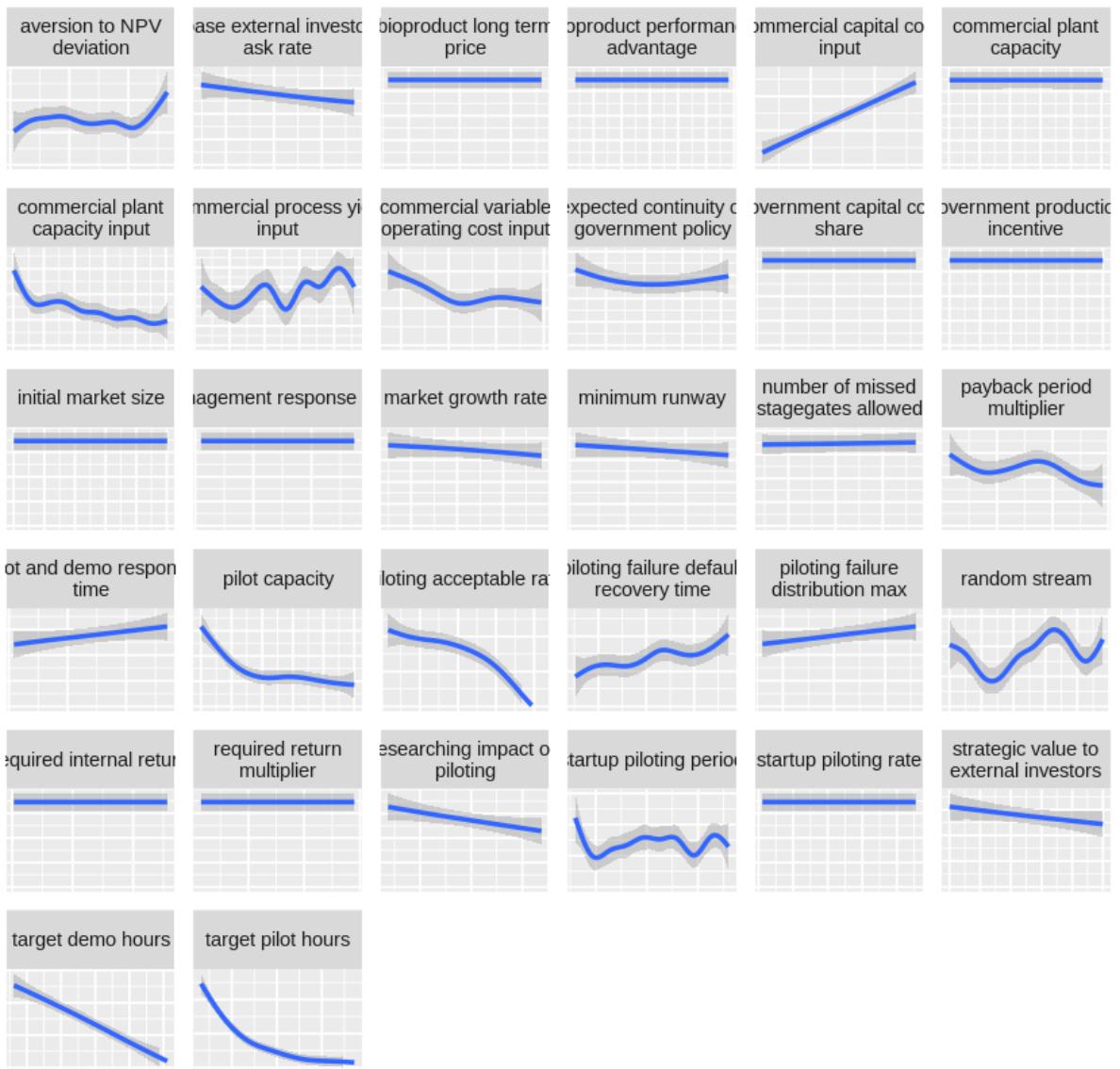
Conditioned Output for demoing progress



Warning message:

"Removed 161 rows containing missing values (geom_smooth)."

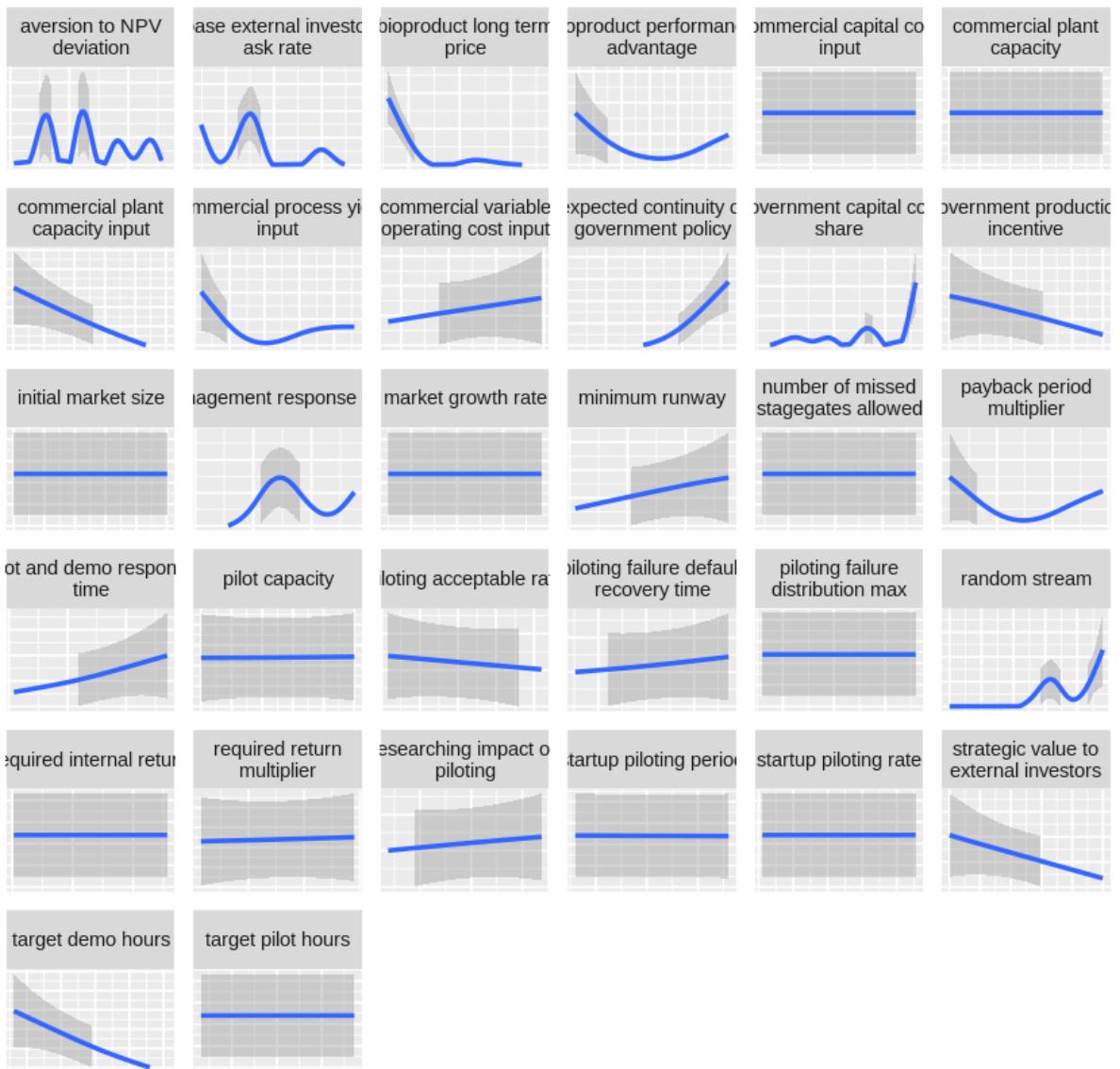
Conditioned Output for demoing complete



Warning message:

"Removed 7 rows containing missing values (geom_smooth)."

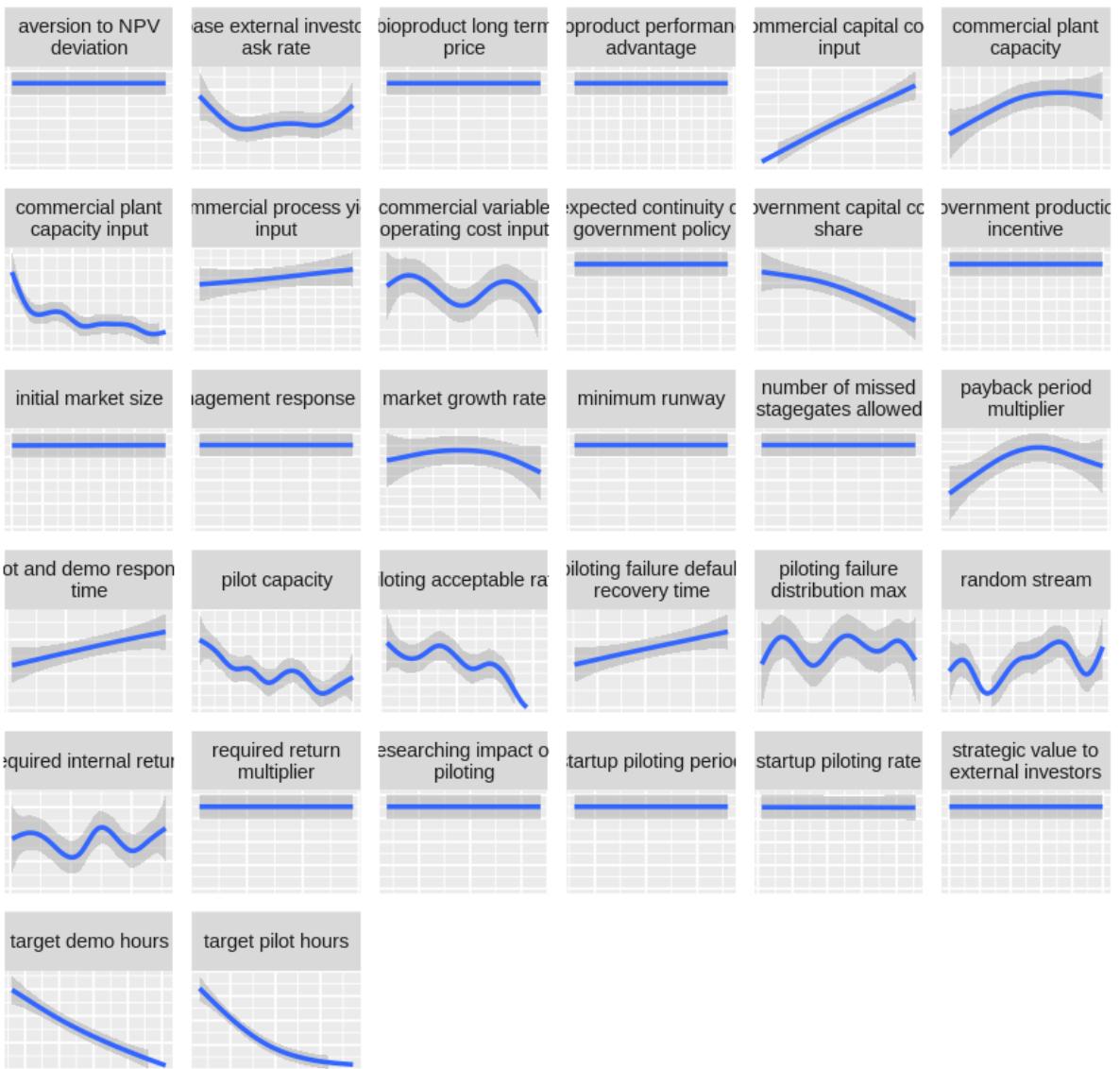
Conditioned Output for regulatory delay



Warning message:

"Removed 70 rows containing missing values (geom_smooth)."

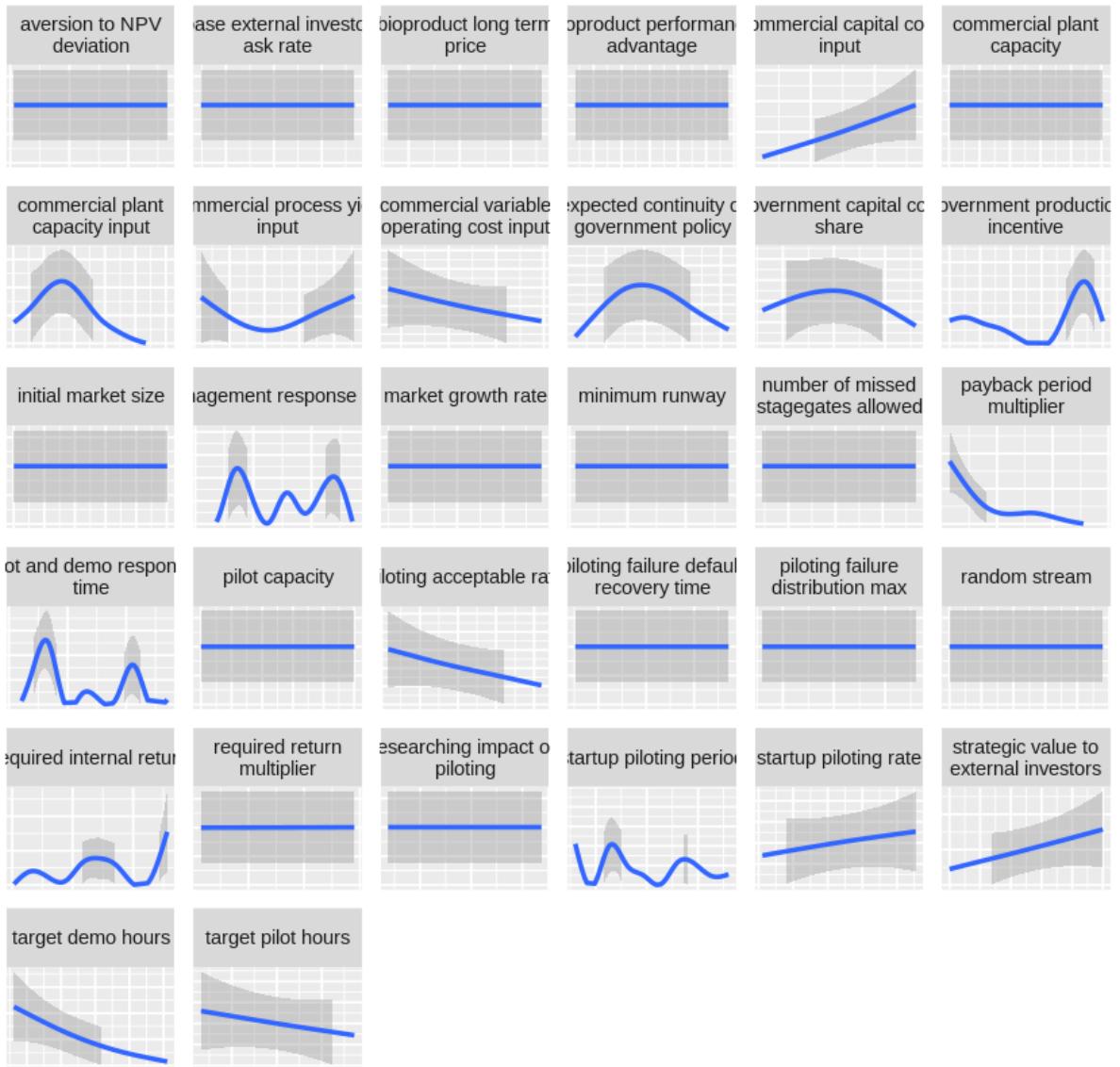
Conditioned Output for precommercial



Warning message:

"Removed 4 rows containing missing values (geom_smooth)."

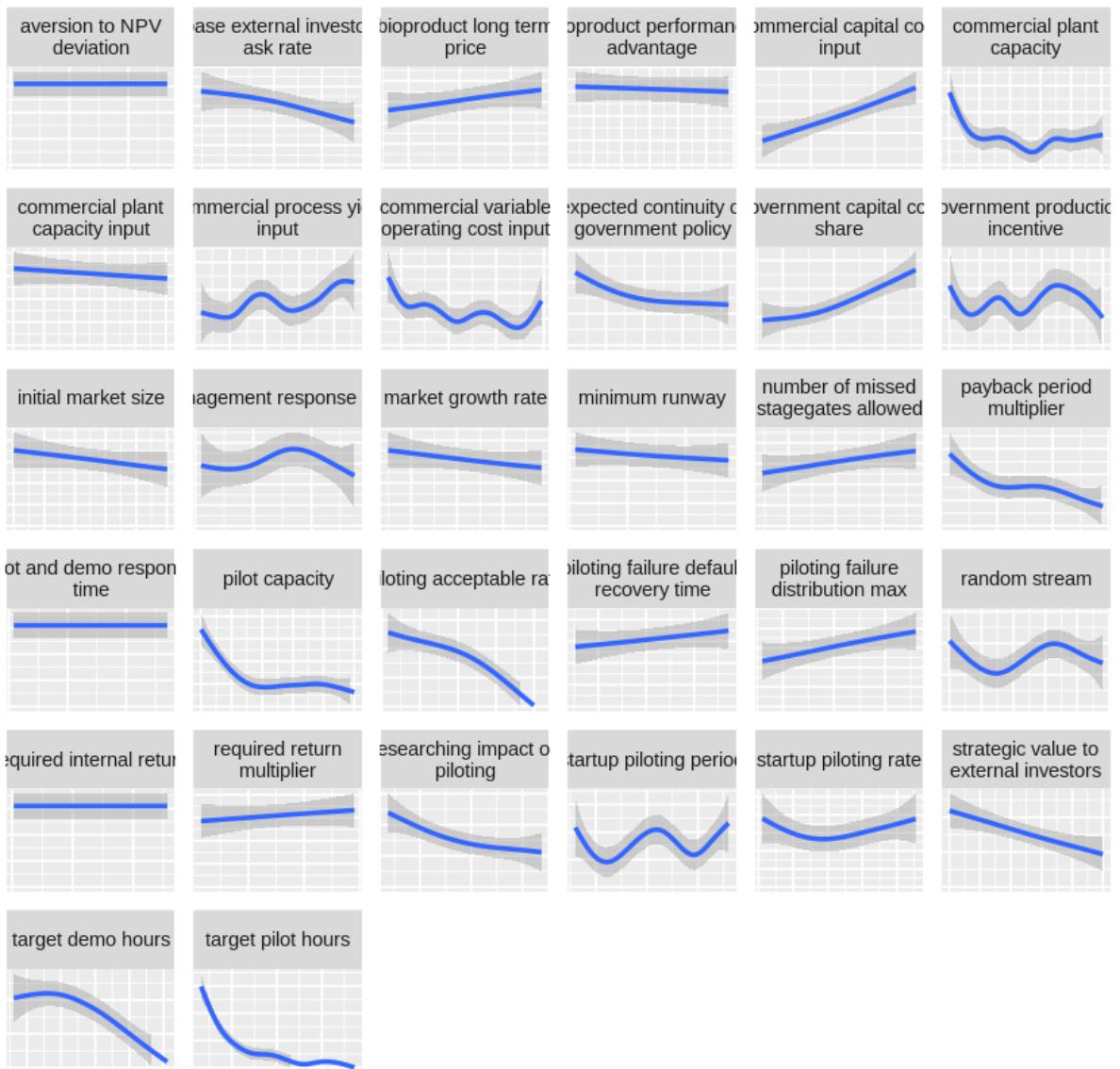
Conditioned Output for commercial plant construction



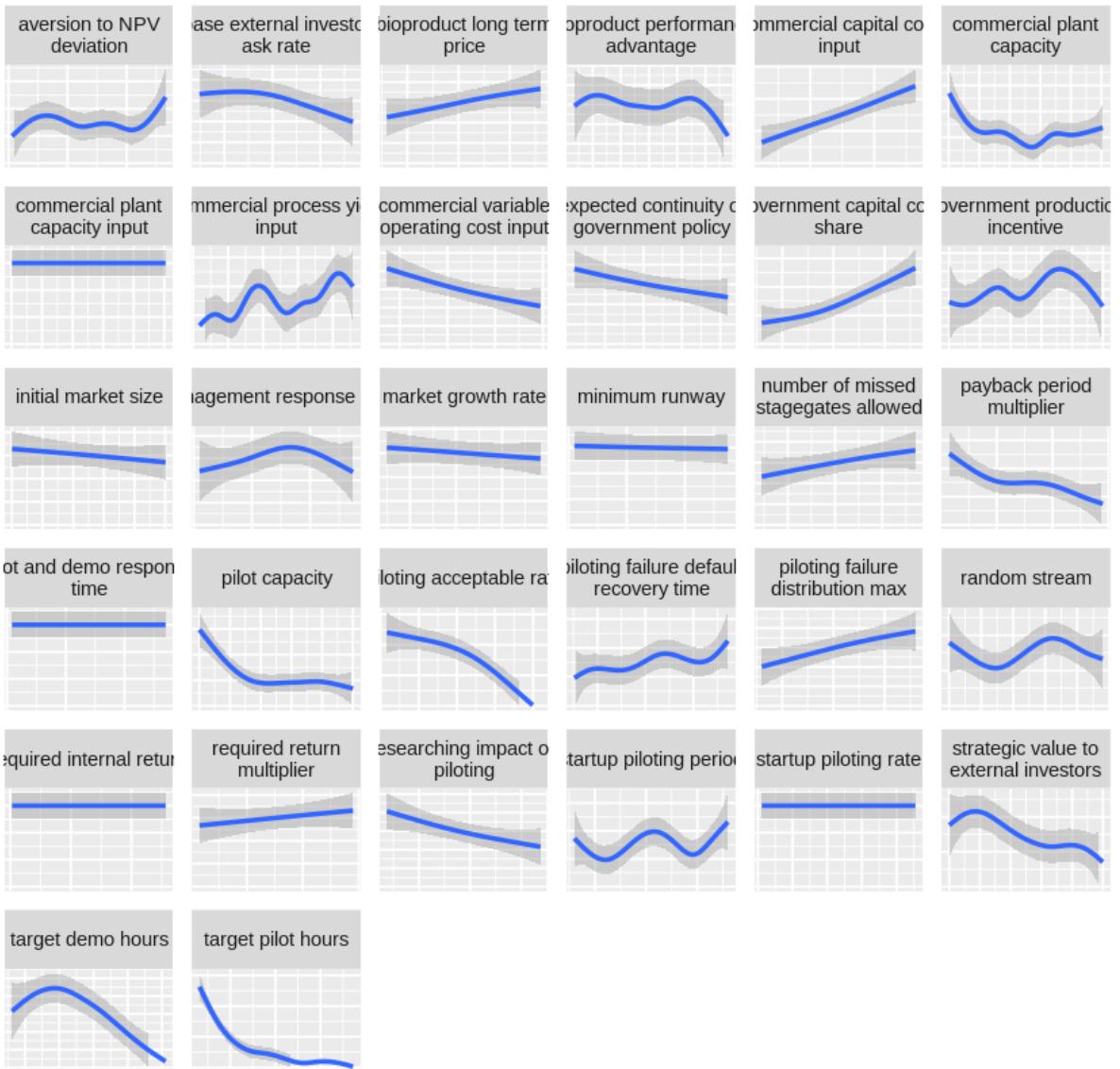
Warning message:

"Removed 4 rows containing missing values (geom_smooth)."

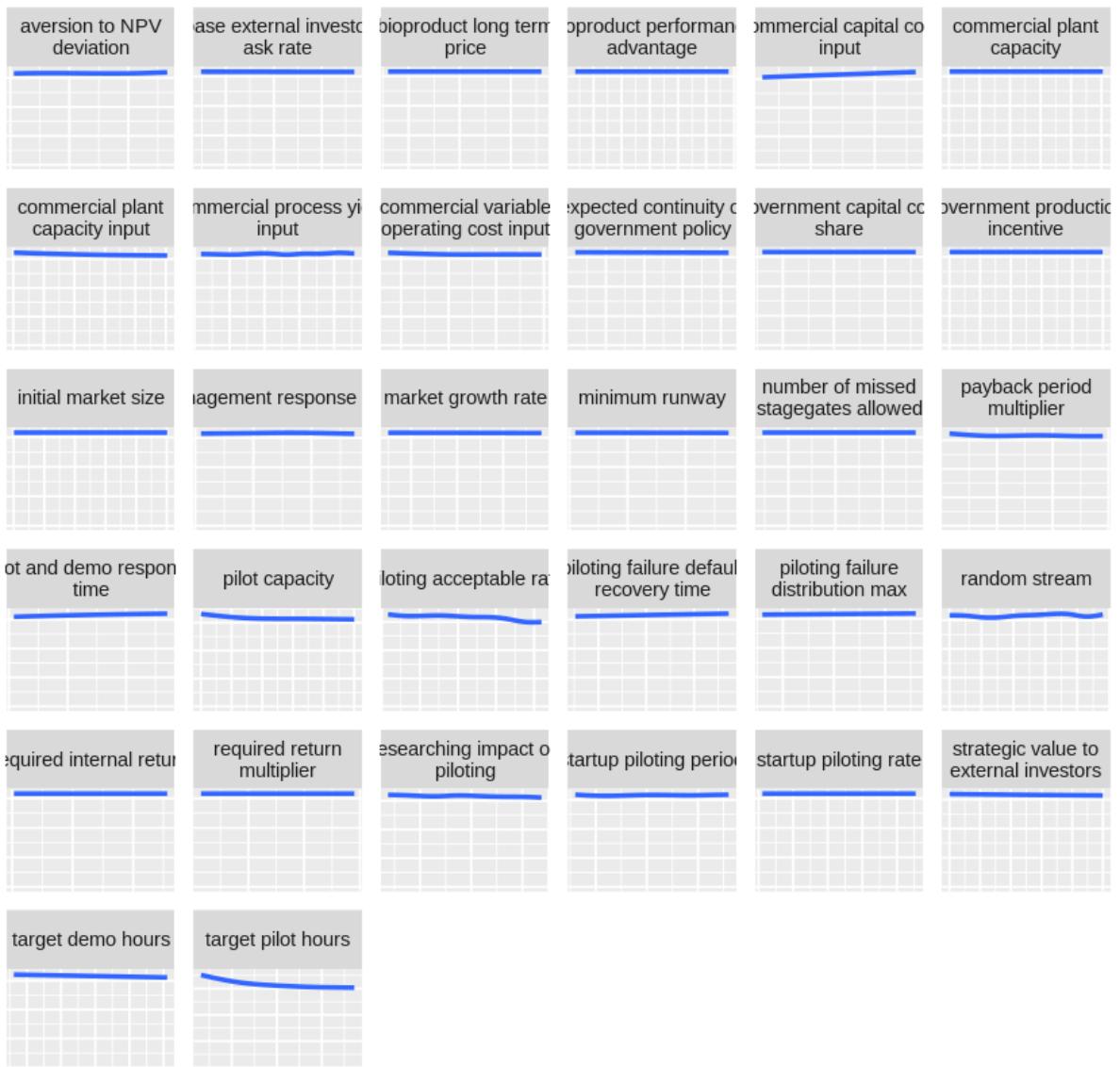
Conditioned Output for commercial plant is built



Conditioned Output for commercial plant operation



Conditioned Output for technology readiness level



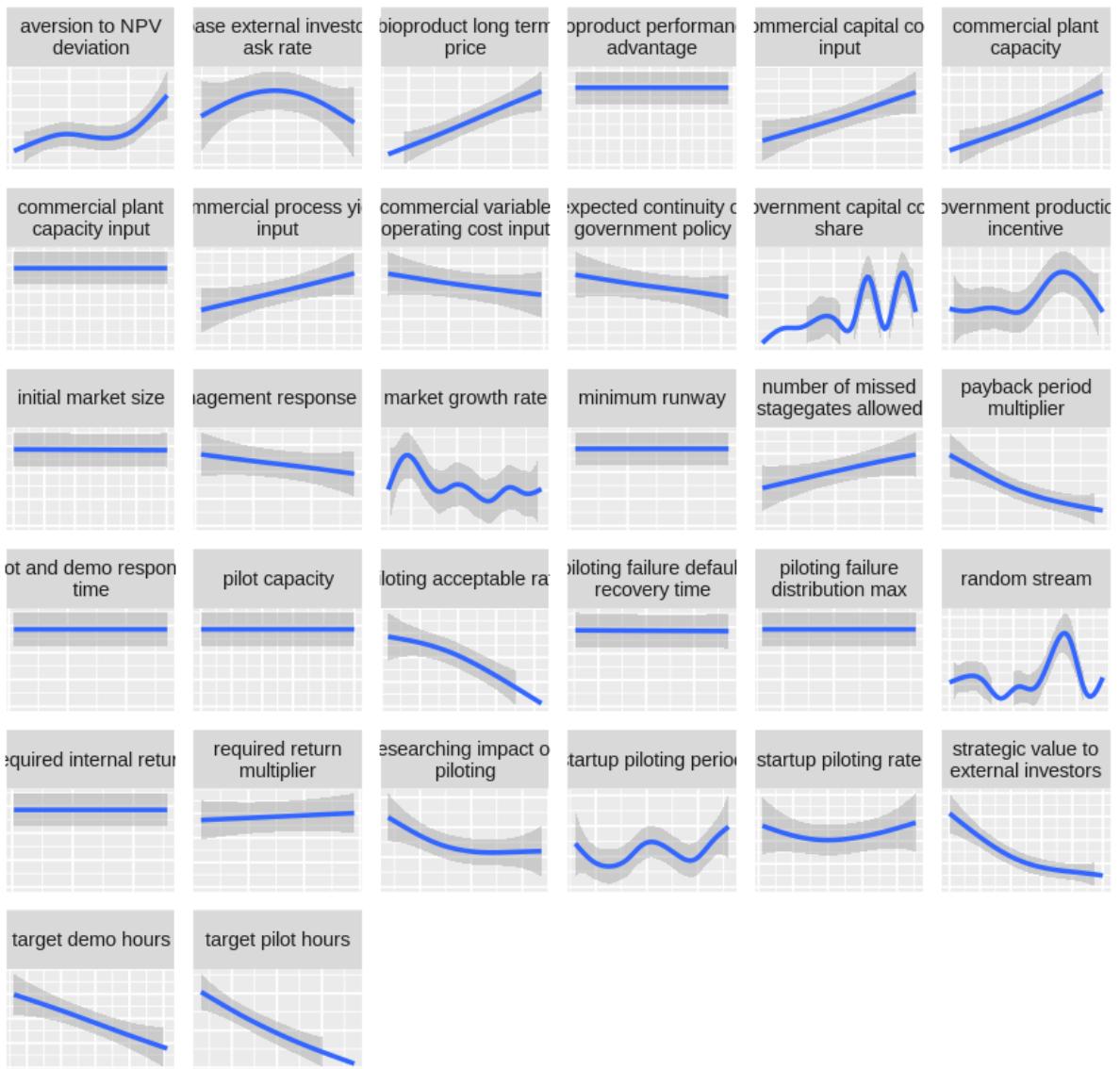
Warning message:

"Removed 96704 rows containing non-finite values (stat_smooth)."

Conditioned Output for stage in progress

aversion to NPV deviation	base external investment ask rate	bioproduct long term price	bioproduct performance advantage	commercial capital cost input	commercial plant capacity
commercial plant capacity input	commercial process yield input	commercial variable operating cost input	expected continuity of government policy	government capital cost share	government production incentive
initial market size	management response	market growth rate	minimum runway	number of missed stagegates allowed	payback period multiplier
ilot and demo response time	pilot capacity	piloting acceptable range	piloting failure default recovery time	piloting failure distribution max	random stream
required internal return	required return multiplier	researching impact on piloting	startup piloting period	startup piloting rate	strategic value to external investors
target demo hours	target pilot hours				

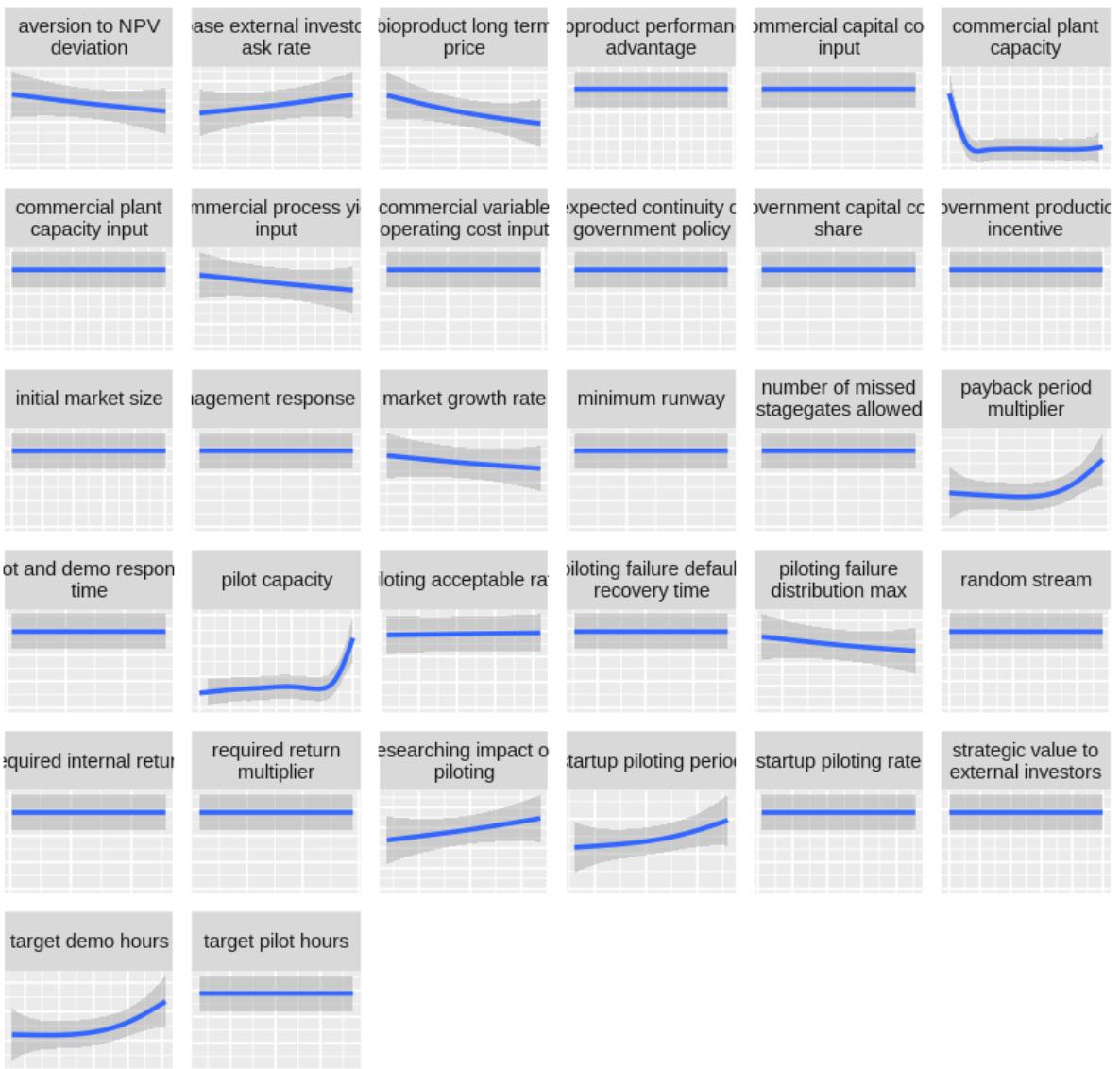
Conditioned Output for BS equity



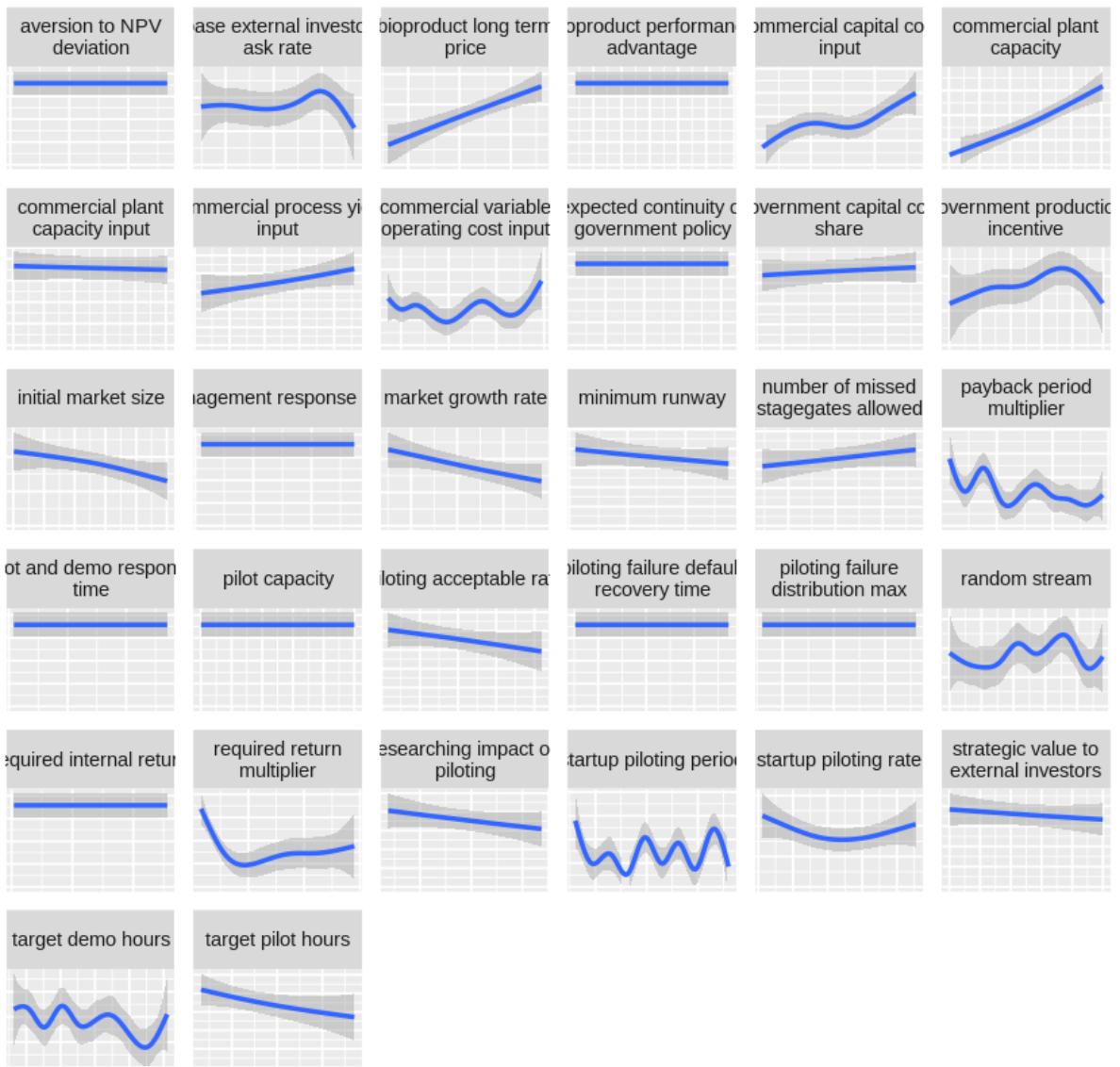
Warning message:

"Removed 122784 rows containing non-finite values (stat_smooth)."

Conditioned Output for payback period



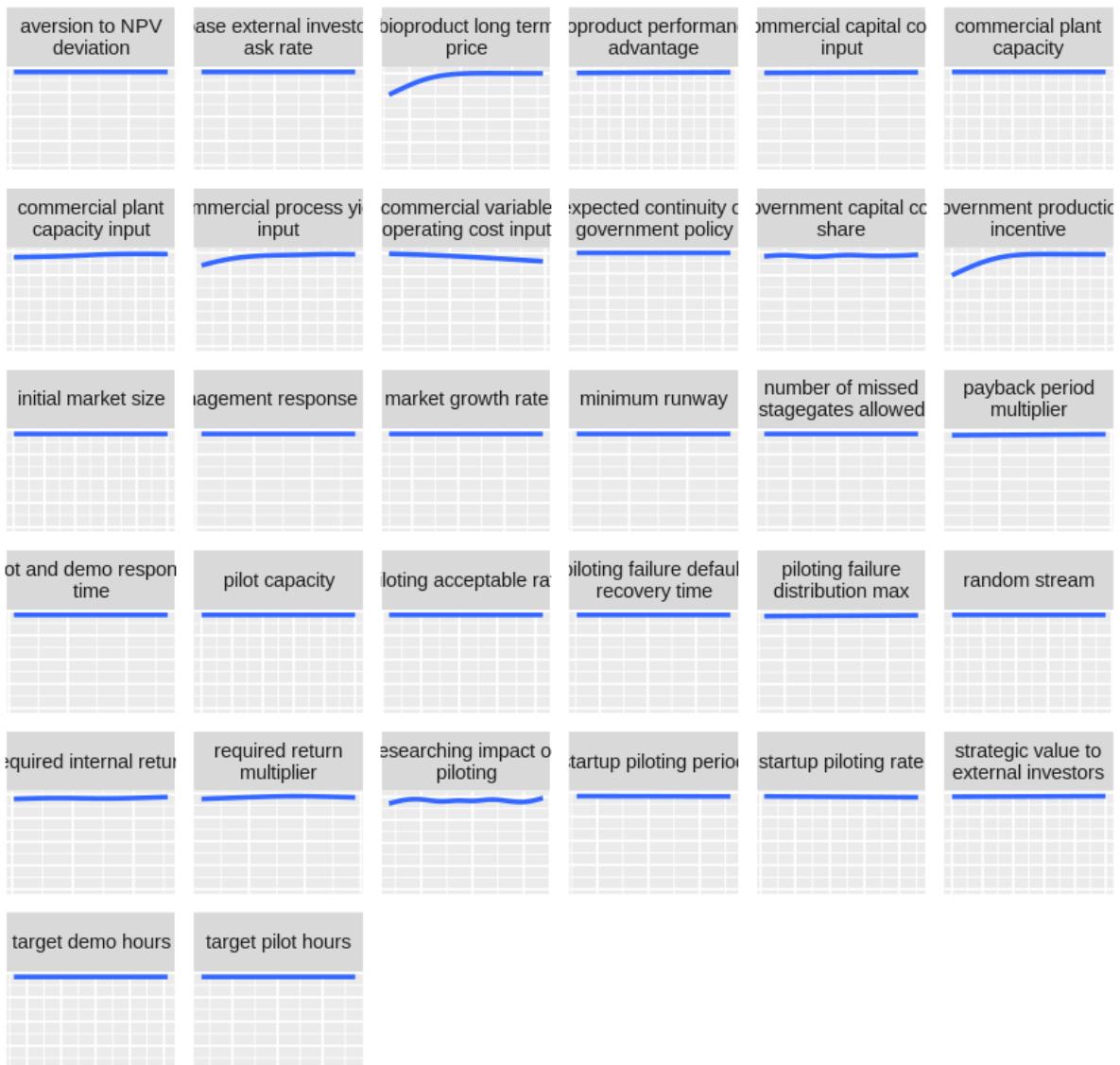
Conditioned Output for NPV at required return



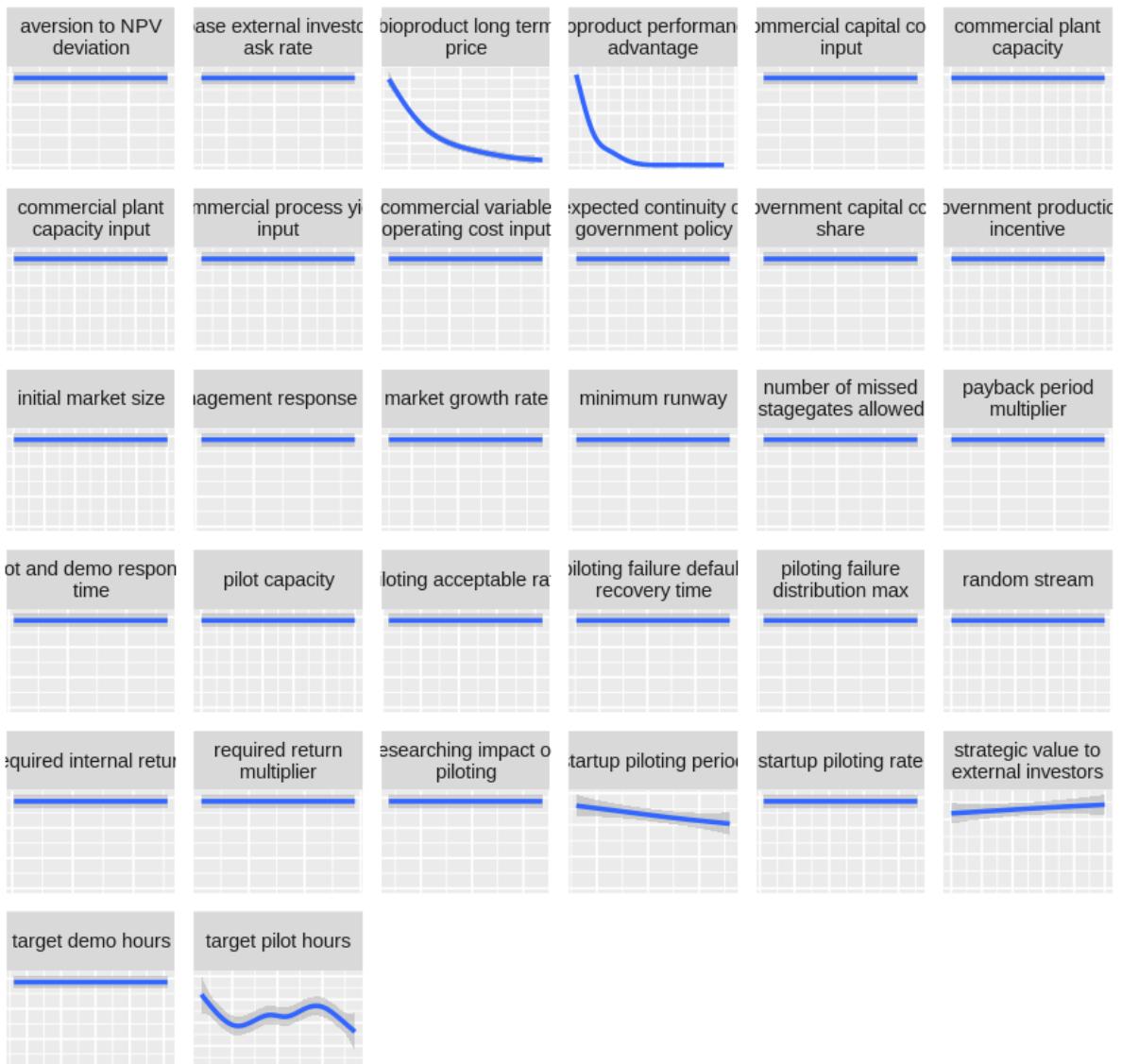
Warning message:

"Removed 22 rows containing missing values (geom_smooth)."

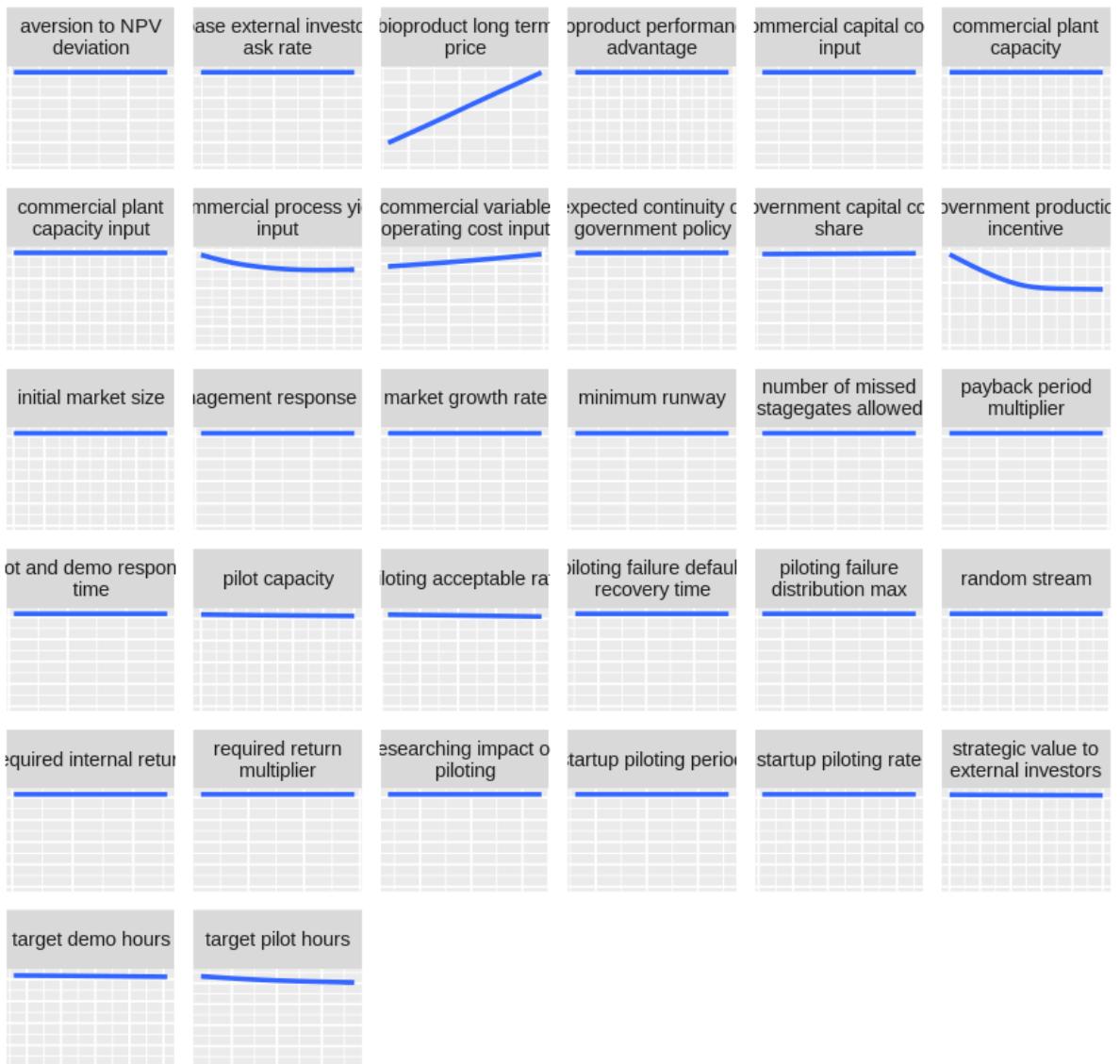
Conditioned Output for profitability indicator



Conditioned Output for bioproduct favorability indicator



Conditioned Output for long term selling price without green premium after market entr



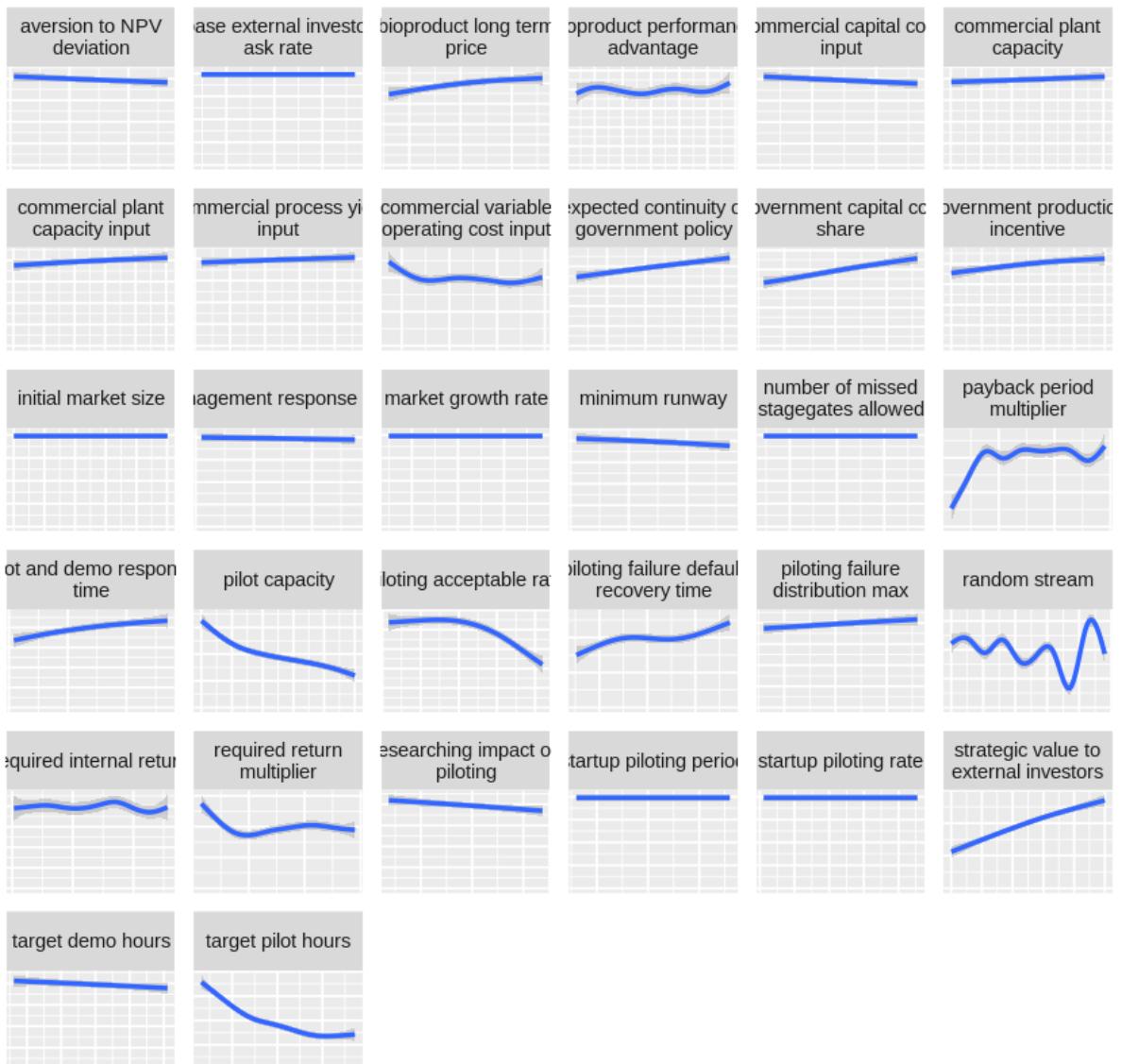
Conditioned Output for total approval cost

aversion to NPV deviation	base external investors ask rate	bioproduct long term price	bioproduct performance advantage	commercial capital cost input	commercial plant capacity
commercial plant capacity input	commercial process yield input	commercial variable operating cost input	expected continuity of government policy	government capital cost share	government production incentive
initial market size	management response	market growth rate	minimum runway	number of missed stagegates allowed	payback period multiplier
ot and demo response time	pilot capacity	piloting acceptable range	piloting failure default recovery time	piloting failure distribution max	random stream
required internal return	required return multiplier	researching impact on piloting	startup piloting period	startup piloting rate	strategic value to external investors
target demo hours	target pilot hours				

Conditioned Output for total approval time

aversion to NPV deviation	base external investors ask rate	bioproduct long term price	bioproduct performance advantage	commercial capital cost input	commercial plant capacity
commercial plant capacity input	commercial process yield input	commercial variable operating cost input	expected continuity of government policy	government capital cost share	government production incentive
initial market size	management response	market growth rate	minimum runway	number of missed stagegates allowed	payback period multiplier
ot and demo response time	pilot capacity	piloting acceptable range	piloting failure default recovery time	piloting failure distribution max	random stream
required internal return	required return multiplier	researching impact of piloting	startup piloting period	startup piloting rate	strategic value to external investors
target demo hours	target pilot hours				

Conditioned Output for in business indicator



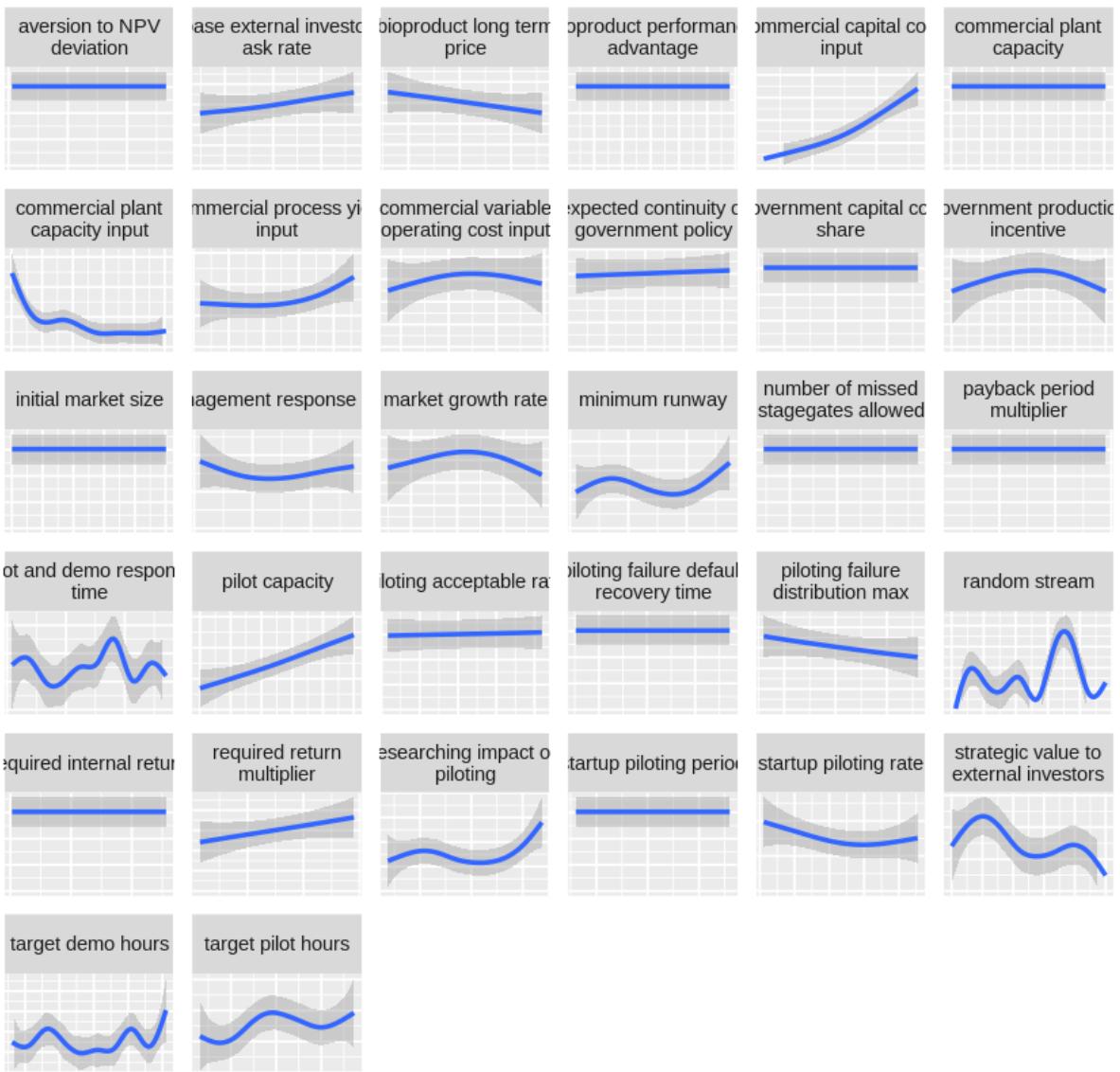
Warning message:

"Removed 2 rows containing missing values (geom_smooth)."

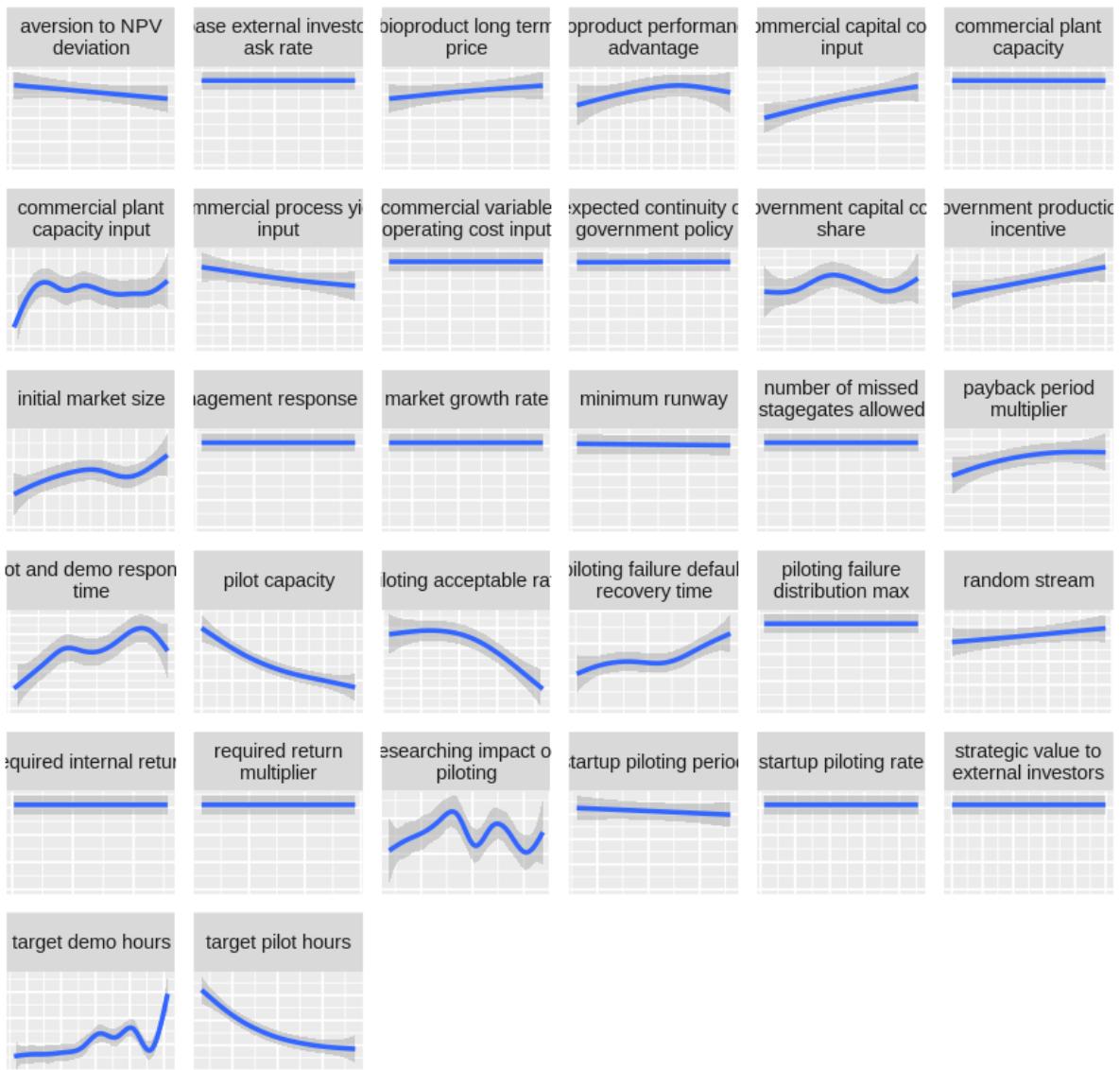
Conditioned Output for internal project cancelled indicator

aversion to NPV deviation	base external investors ask rate	bioproduct long term price	bioproduct performance advantage	commercial capital cost input	commercial plant capacity
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
commercial plant capacity input	commercial process yield input	commercial variable operating cost input	expected continuity of government policy	government capital cost share	government production incentive
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
initial market size	management response	market growth rate	minimum runway	number of missed stagegates allowed	payback period multiplier
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
ot and demo response time	pilot capacity	piloting acceptable range	piloting failure default recovery time	piloting failure distribution max	random stream
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
required internal return	required return multiplier	researching impact of piloting	startup piloting period	startup piloting rate	strategic value to external investors
<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>	<input type="text"/>
target demo hours	target pilot hours				
<input type="text"/>	<input type="text"/>				

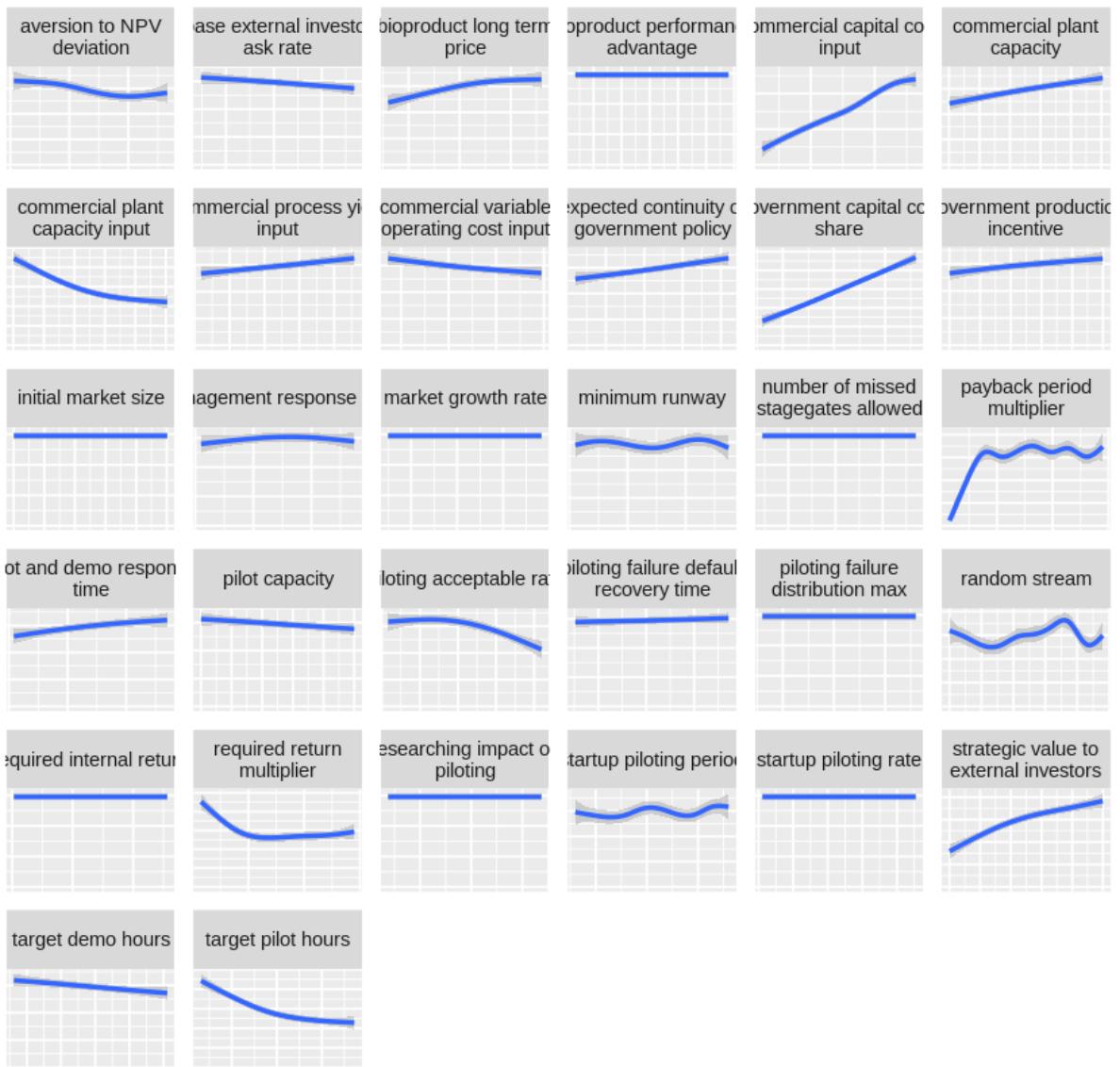
Conditioned Output for investing



Conditioned Output for granting



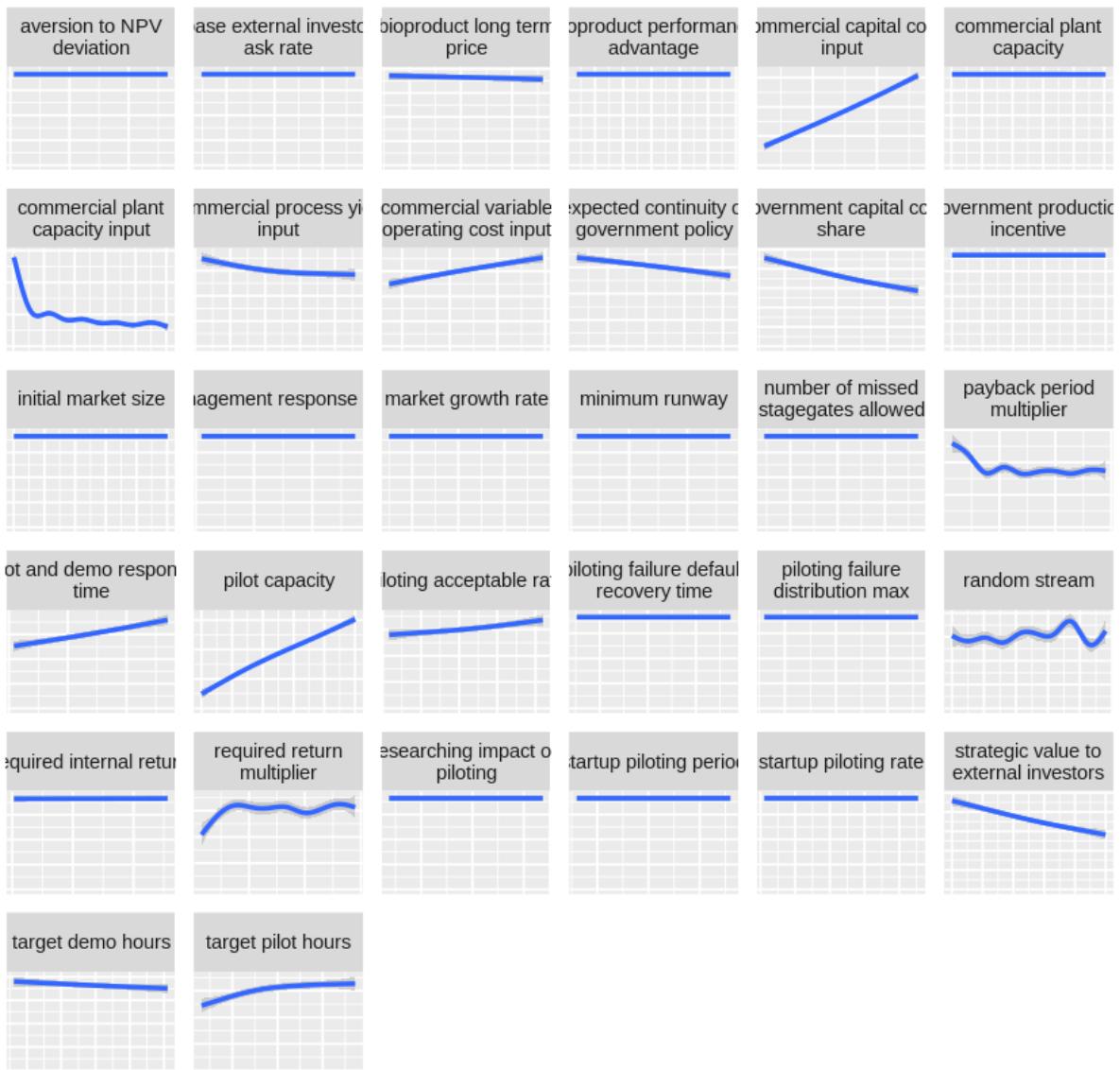
Conditioned Output for Total Government Grants



Warning message:

"Removed 96704 rows containing non-finite values (stat_smooth)."

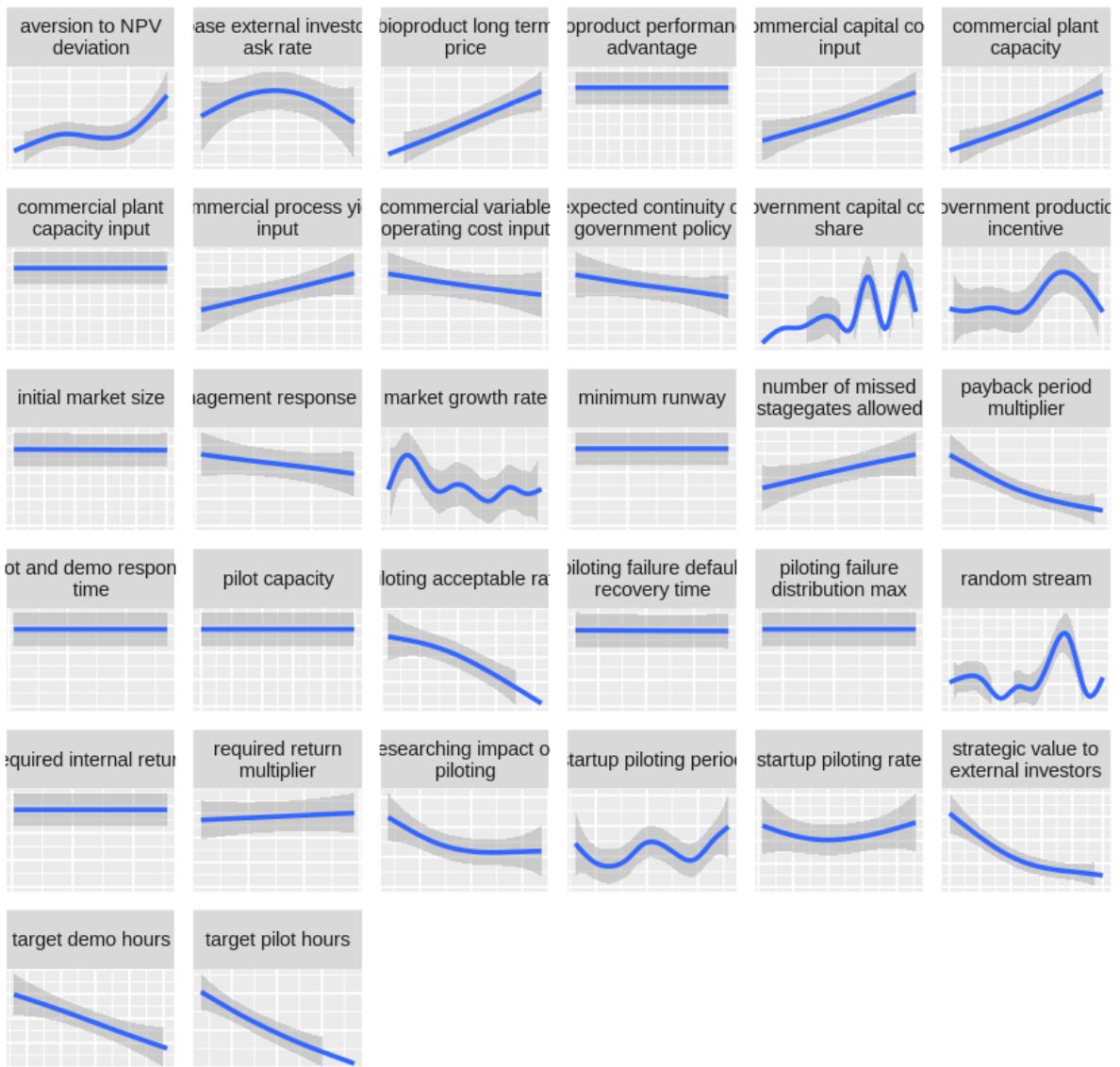
Conditioned Output for Total Investment



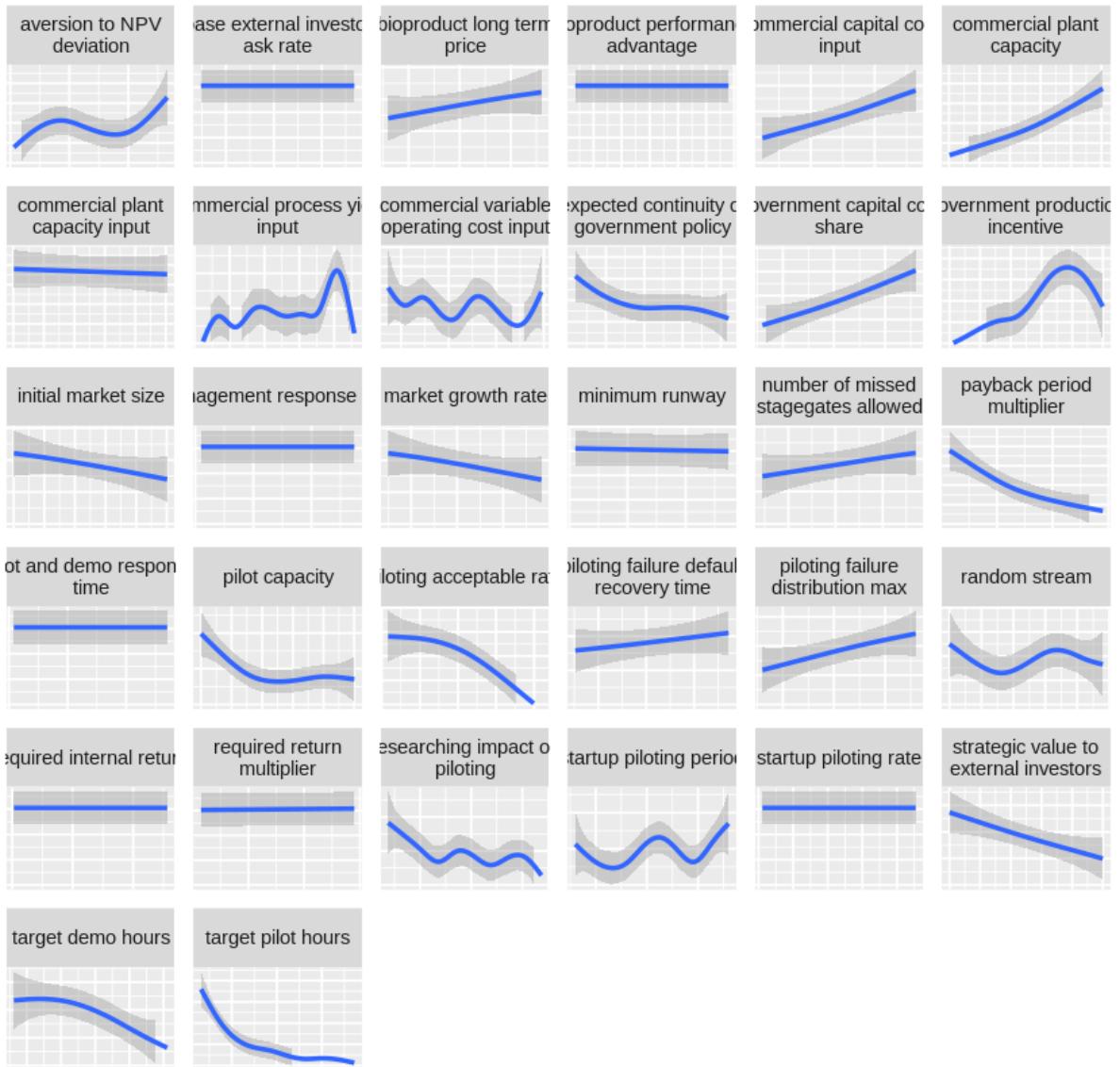
Warning message:

"Removed 7 rows containing missing values (geom_smooth)."

Conditioned Output for Working Capital



Conditioned Output for IS production incentive



Sampling density.

```
In [13]: st <- merge(
  xy
,   xy[i == 1, .(scale = sum(abs(ya - yb)^2)), by = .(l)][scale > 0]
,   by = "l"
)[, .(
  j, i, l
,   xa, xb
,   s = abs(yb - yaib)^2 / scale
,   t = abs(ya - yaib)^2 / scale
)][order(j, i, l)]
z.local <- melt(
  melt(
    st[, .(
      Observation = j
,     Input      = colnames(z.inputs )[1+i]
,     Output     = colnames(z.outputs)[4+l]
,     a          = xa
,     b          = xb
,     First      = s
,     Total      = t
    )]
,   id.vars = c("Observation", "Input", "Output", "First", "Total")
,   variable.name = "Block"
,   value.name = "x"
)
,   id.vars = c("Observation", "Input", "Output", "Block", "x")
,   variable.name = "Sensitivity"
,   value.name = "Index"
)
z.local %>% head
```

A data.table: 6 x 7

Observation	Input	Output	Block	x	Sensitivity	Index
<int>	<chr>	<chr>	<fct>	<dbl>	<fct>	<dbl>
1	aversion to NPV deviation	bioproduct market share mass	a	0.06	First	0
1	aversion to NPV deviation	current market size economic	a	0.06	First	0
1	aversion to NPV deviation	current market size mass	a	0.06	First	0
1	aversion to NPV deviation	long term market share	a	0.06	First	0
1	aversion to NPV deviation	long term market value	a	0.06	First	0
1	aversion to NPV deviation	Adopters	a	0.06	First	0

```
In [14]: epsilon <- 1e-5
z.density <- z.local[
  Sensitivity == "Total" # & Index > 0
, .(
  xmin = min(x) - epsilon / 2
, xmax = max(x) + epsilon / 2
, Index = mean(Index)
, Weight = 1
)
, by = .(Input, Output, Observation)
][, .(
  Input
, Output
, xmin
, xmax
, Index = Index / (xmax - xmin + epsilon)
, Weight = Weight / (xmax - xmin + epsilon)
)]
z.density <- rbind(
  z.density[, .(x = xmin, Index , Weight ), by = .
  (Input, Output)]
, z.density[, .(x = xmax, Index = - Index, Weight = - Weight), by = .
  (Input, Output)]
)[order(Input, Output, x)][, .(x, Index = cumsum(Index), Weight = cumsum
(Weight)), by = .(Input, Output)]
z.density %>% head
```

A data.table: 6 x 5

Input	Output	x	Index	Weight
<chr>	<chr>	<dbl>	<dbl>	<dbl>
aversion to NPV deviation	Adopters	0.05999500	0	50000.000000
aversion to NPV deviation	Adopters	0.06000500	0	0.000000
aversion to NPV deviation	Adopters	0.06126453	0	5.181649
aversion to NPV deviation	Adopters	0.06126453	0	6.795721
aversion to NPV deviation	Adopters	0.06253406	0	7.648187
aversion to NPV deviation	Adopters	0.06253406	0	10.020642

```
In [15]: for (outname in z.density[, unique(Output)]) {  
  g <- ggplot(  
    z.density[Output == outname  
      , .(Density = sum(Index) / (sum(Weight) + 1e-10)), by = .(Input, Output, x)  
      ][  
      order(Input, Output, x)  
    ]  
  , aes(x = x, y = Density)  
  ) +  
  geom_smooth(method = "gam", formula = y ~ s(x, bs = "cs")) +  
  scale_y_continuous(limits = c(0, NA)) +  
  facet_wrap(. ~ Input, scales = "free", labeller = label_wrap_gen())  
+  
  ggtitle(paste("Variance-Based Sampling Density for", outname)) +  
  theme(  
    axis.title.x = element_blank()  
  , axis.text.x = element_blank()  
  , axis.ticks.x = element_blank()  
  , axis.title.y = element_blank()  
  , axis.text.y = element_blank()  
  , axis.ticks.y = element_blank()  
  )  
  print(g)  
}
```

Warning message:

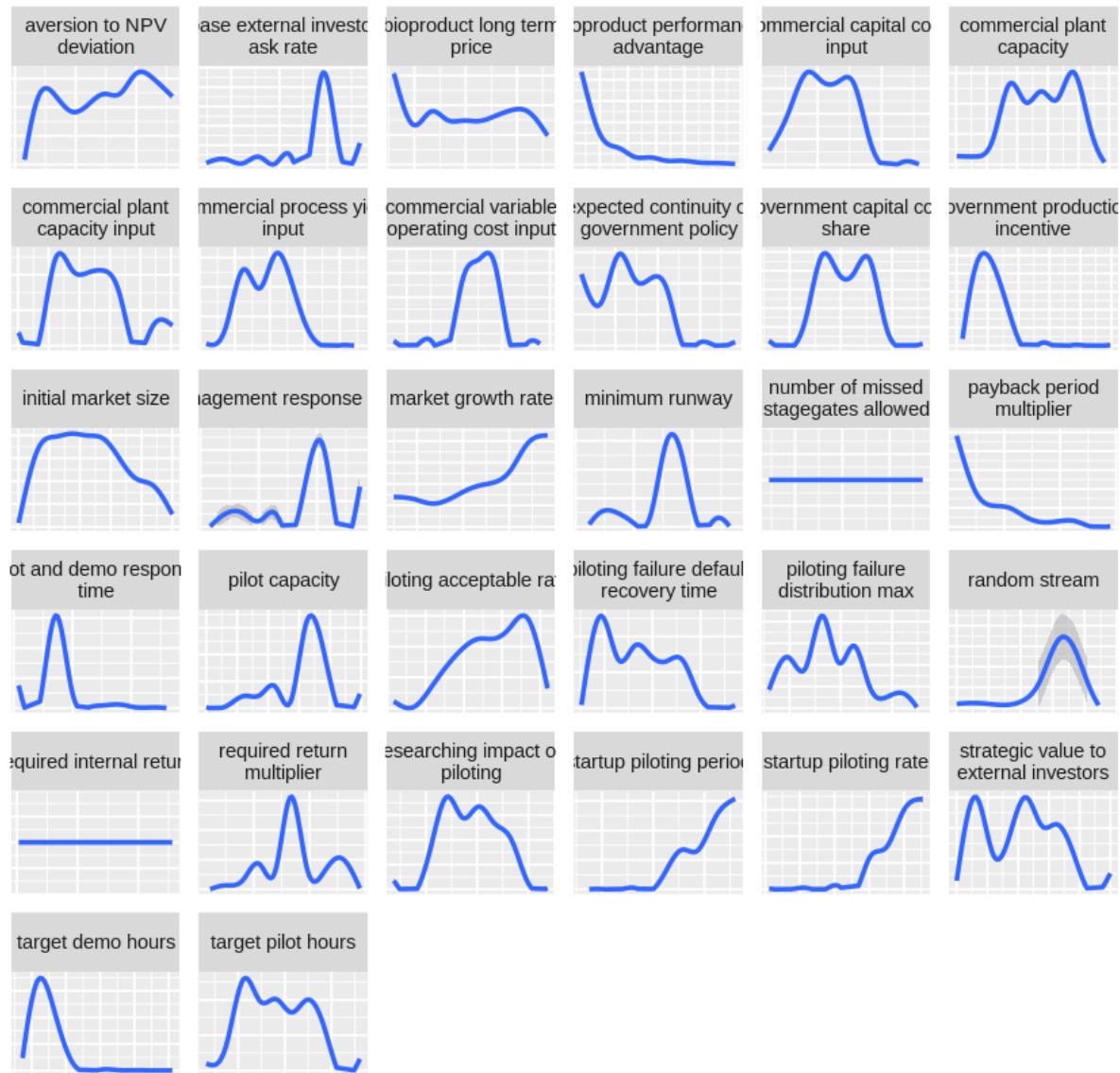
"Removed 512 rows containing non-finite values (stat_smooth)."Warning message:

"Removed 311 rows containing missing values (geom_smooth)."Warning message:

"Removed 57 rows containing non-finite values (stat_smooth)."Warning message:

"Removed 132 rows containing missing values (geom_smooth)." "

Variance-Based Sampling Density for Adopters

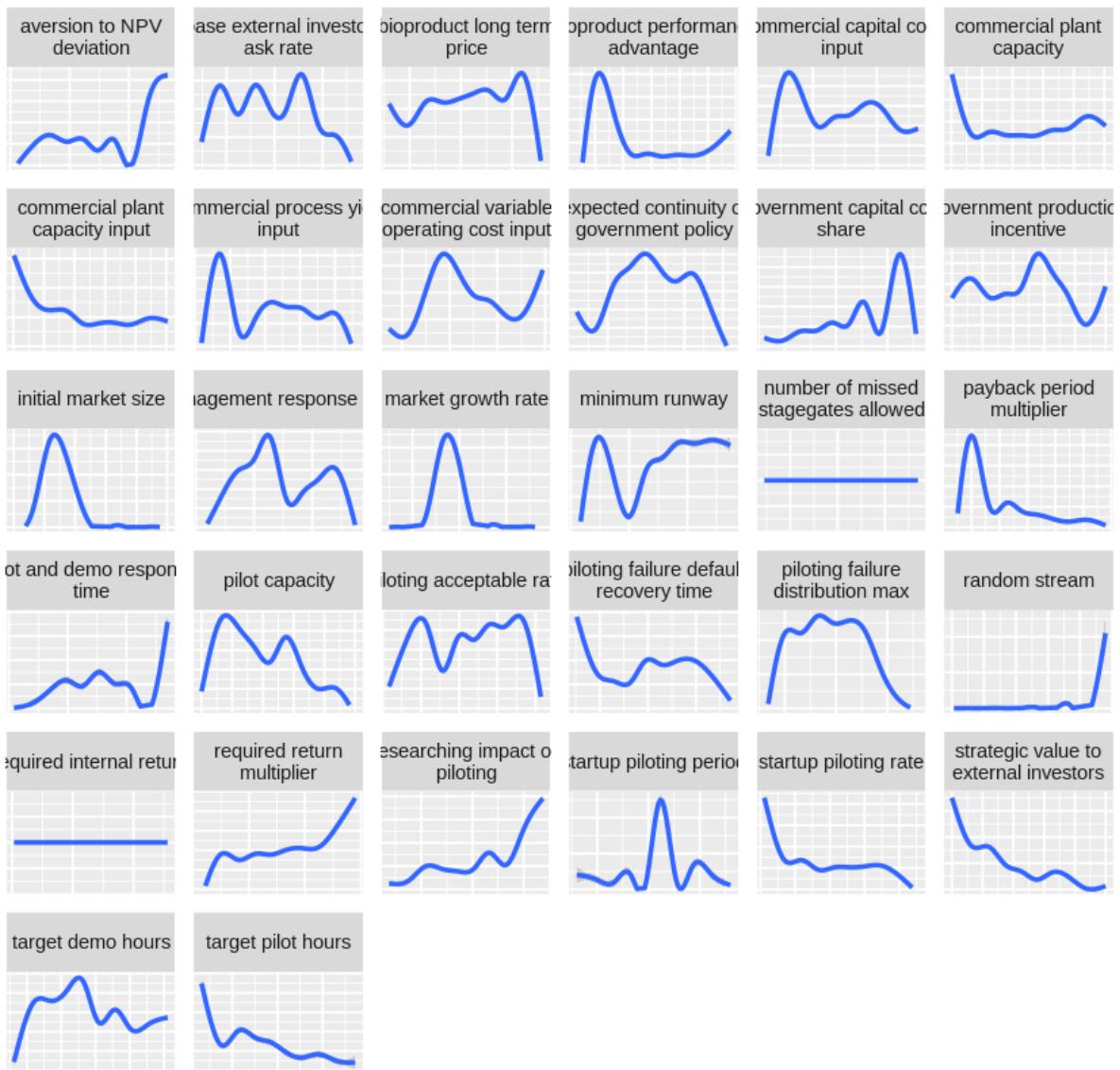


Warning message:

"Removed 74 rows containing non-finite values (stat_smooth)."Warning message:

"Removed 53 rows containing missing values (geom_smooth)." "

Variance-Based Sampling Density for BS equity

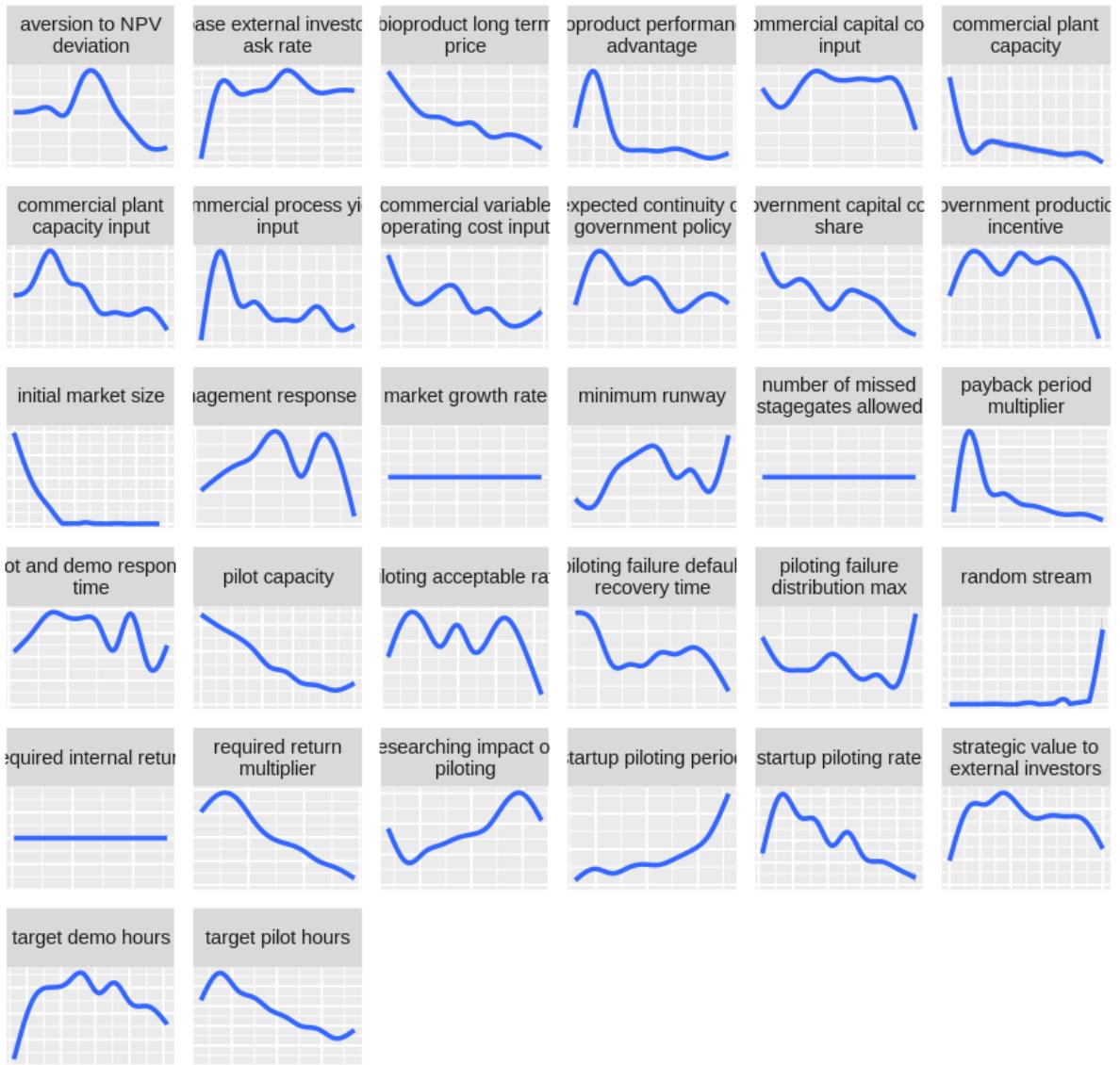


Warning message:

"Removed 134 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 101 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for Cumulative Demoing Production

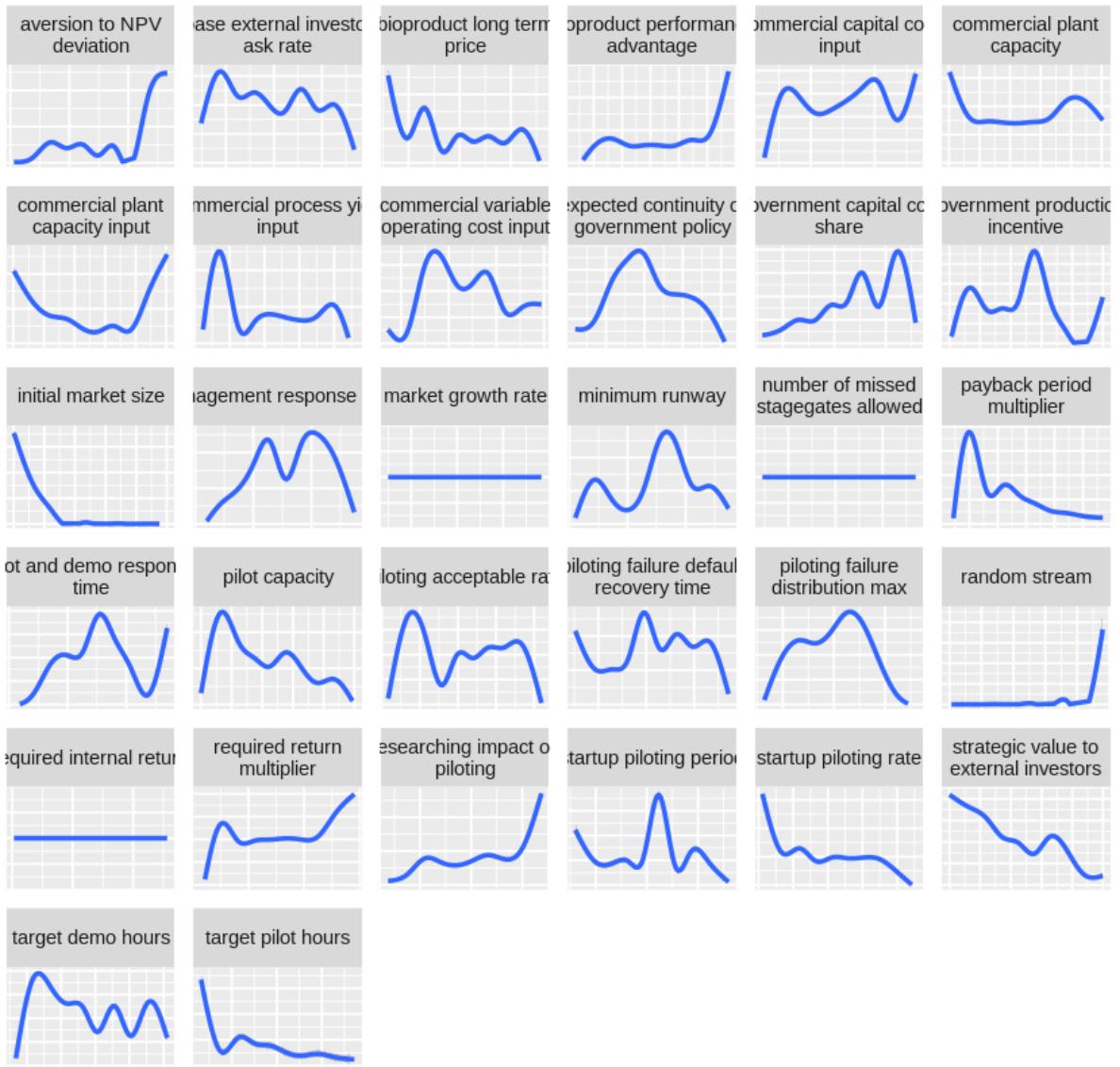


Warning message:

"Removed 399 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 46 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for Cumulative Production

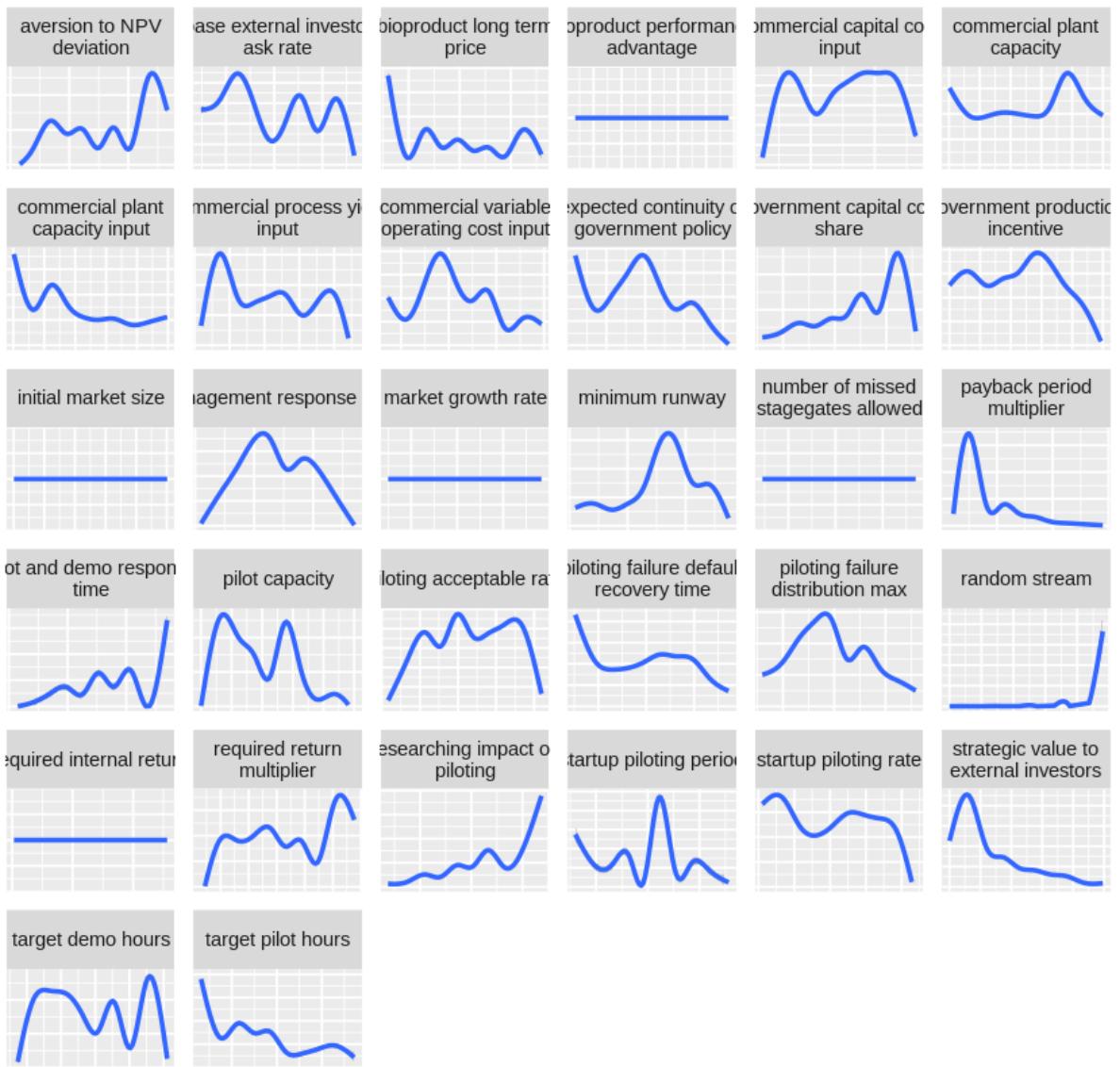


Warning message:

"Removed 89 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 71 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for IS production incentive



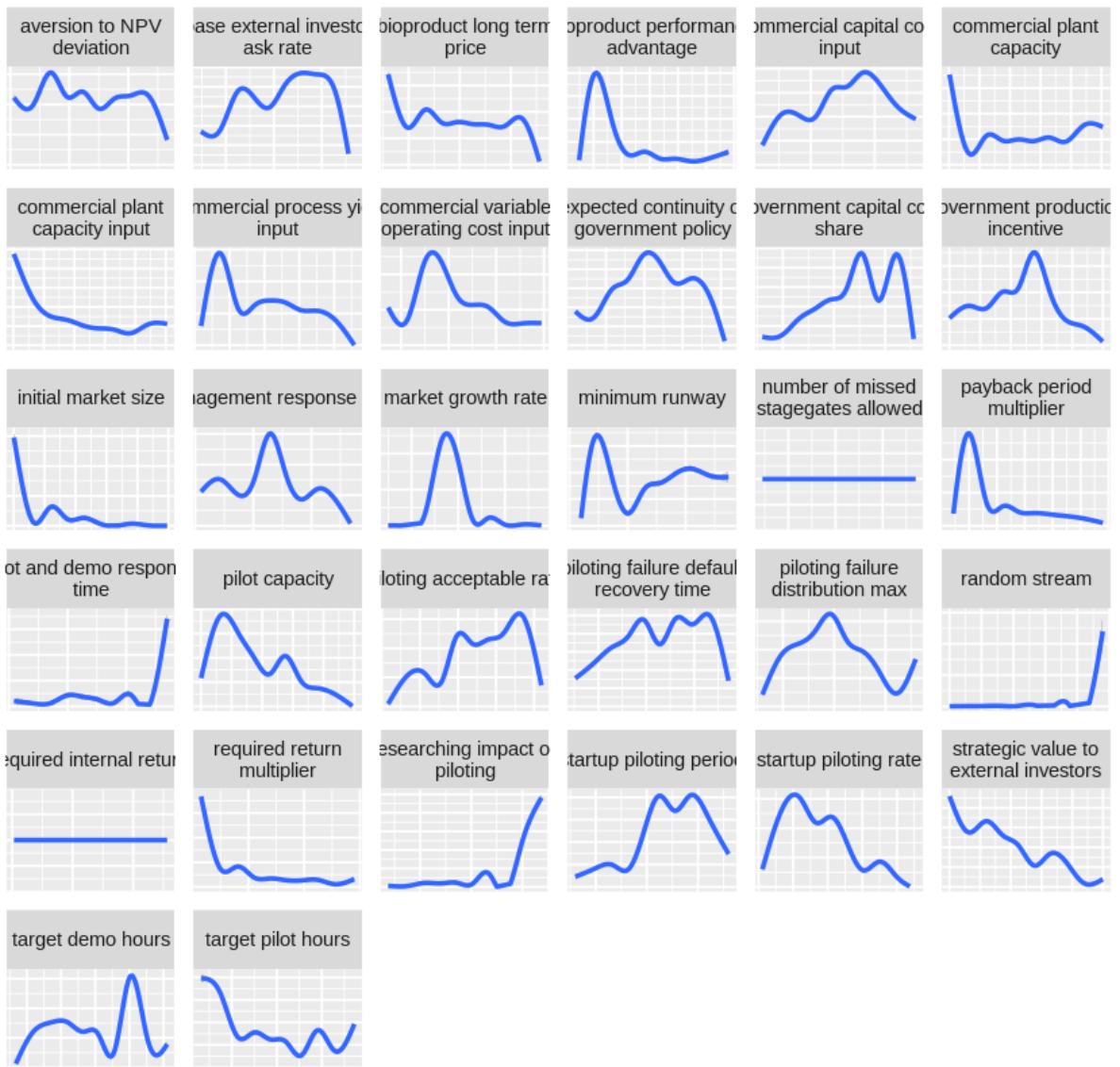
Warning message:

"Removed 1049 rows containing non-finite values (stat_smooth)."

Warning message:

"Removed 214 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for NPV at required return

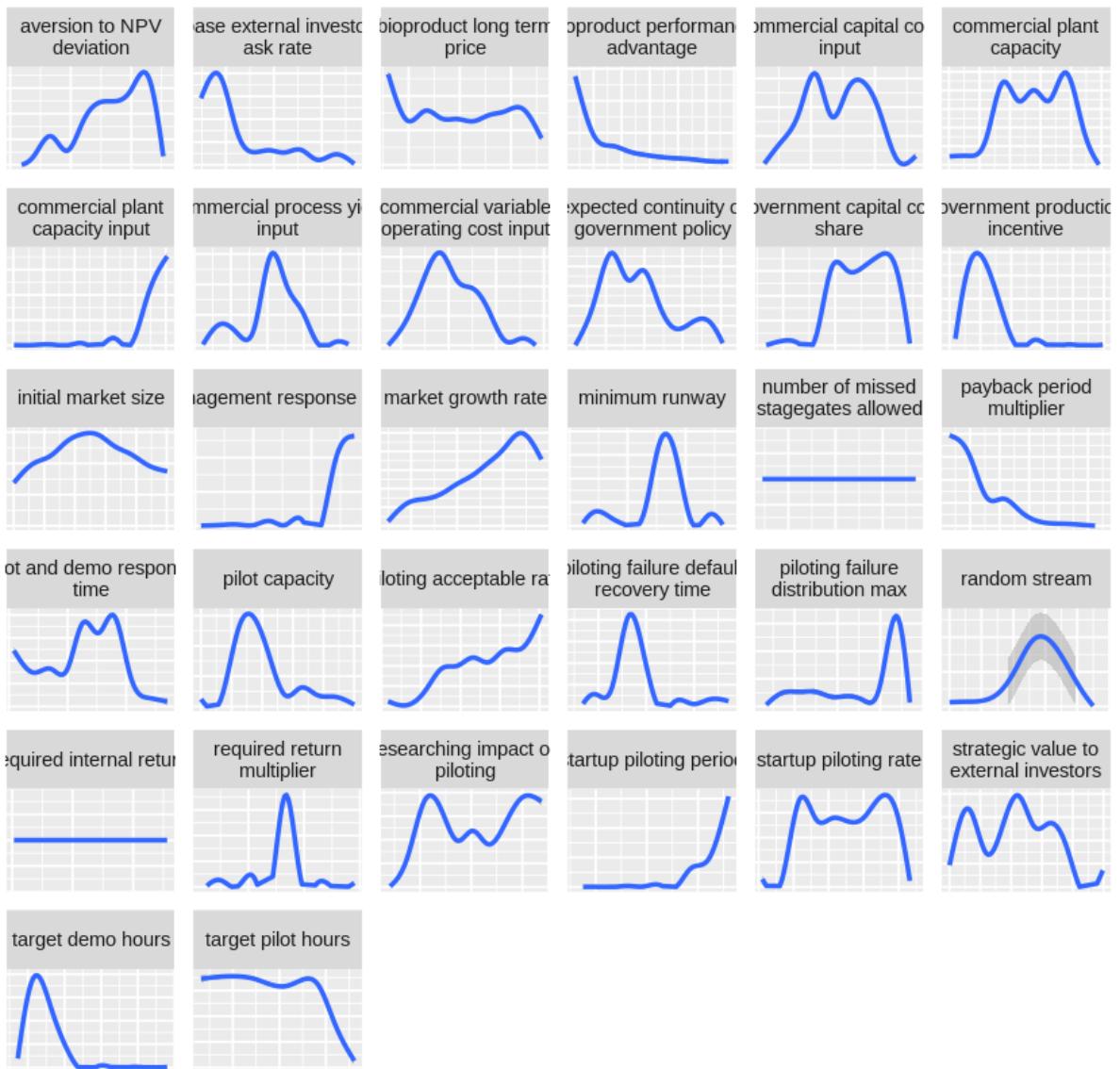


Warning message:

"Removed 313 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 349 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for NonAdopters

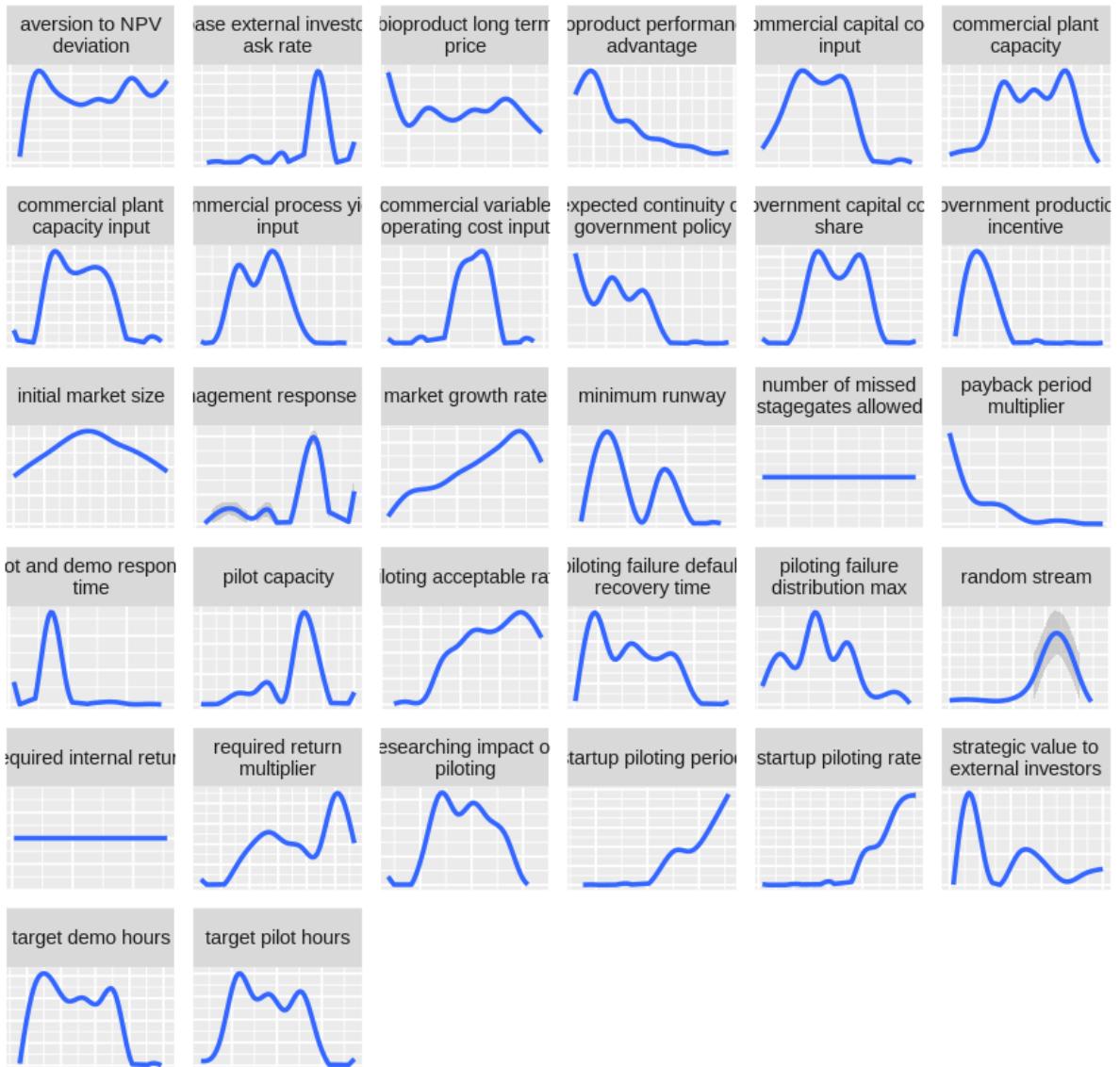


Warning message:

"Removed 23 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 48 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for Potential Adopters

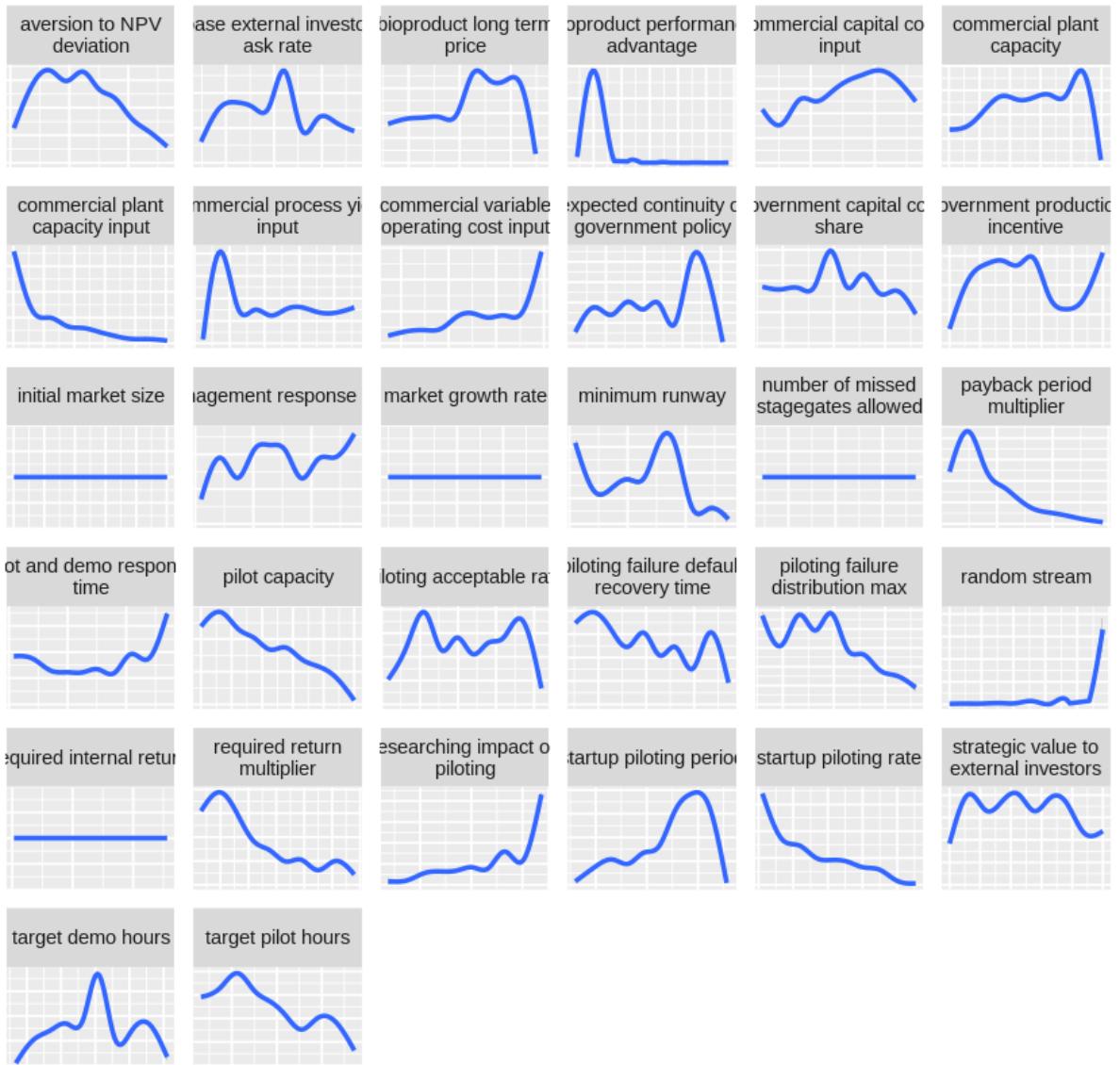


Warning message:

"Removed 118 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 79 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for Total Government Grants

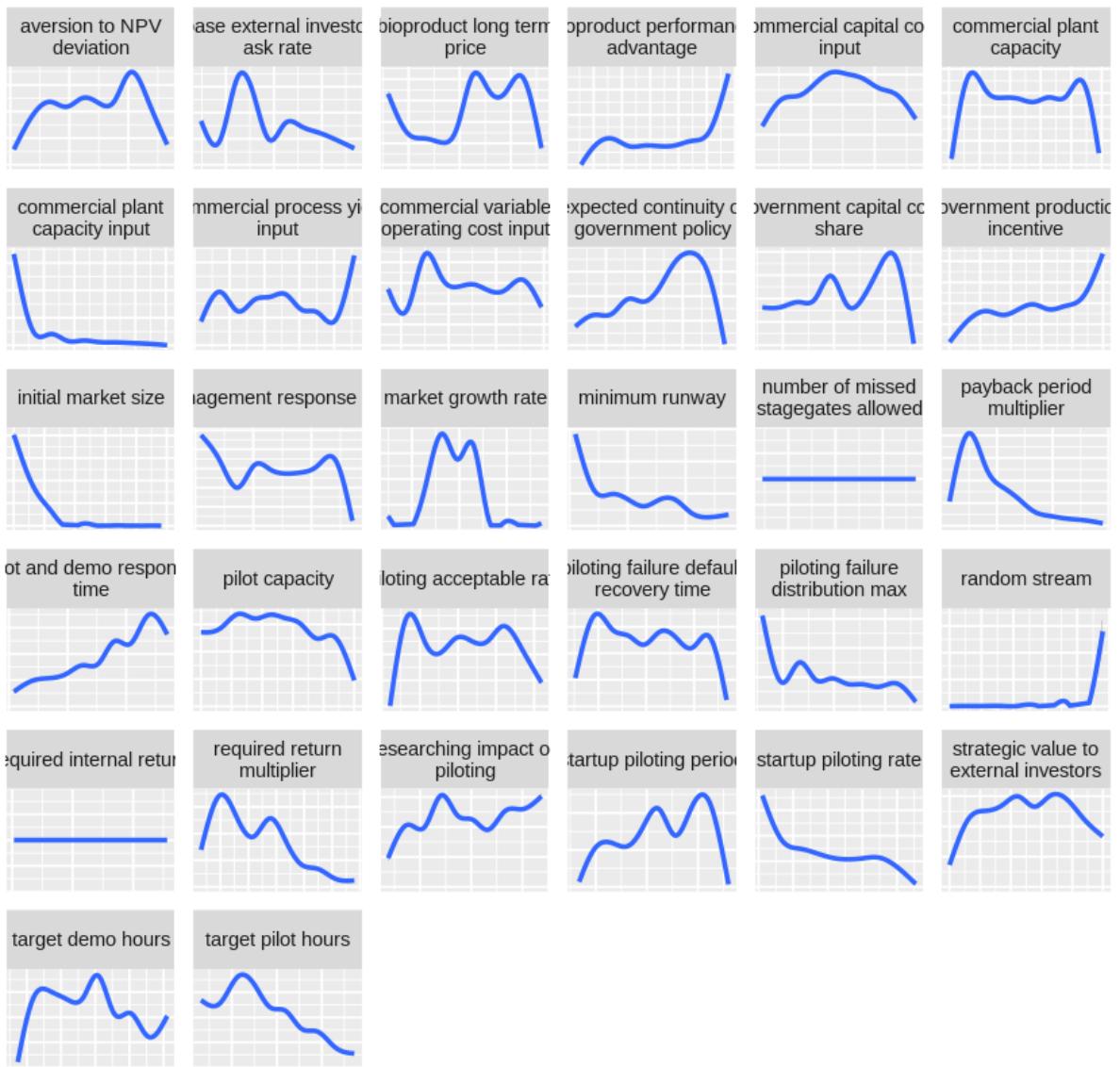


Warning message:

"Removed 57 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 132 rows containing missing values (geom_smooth)."

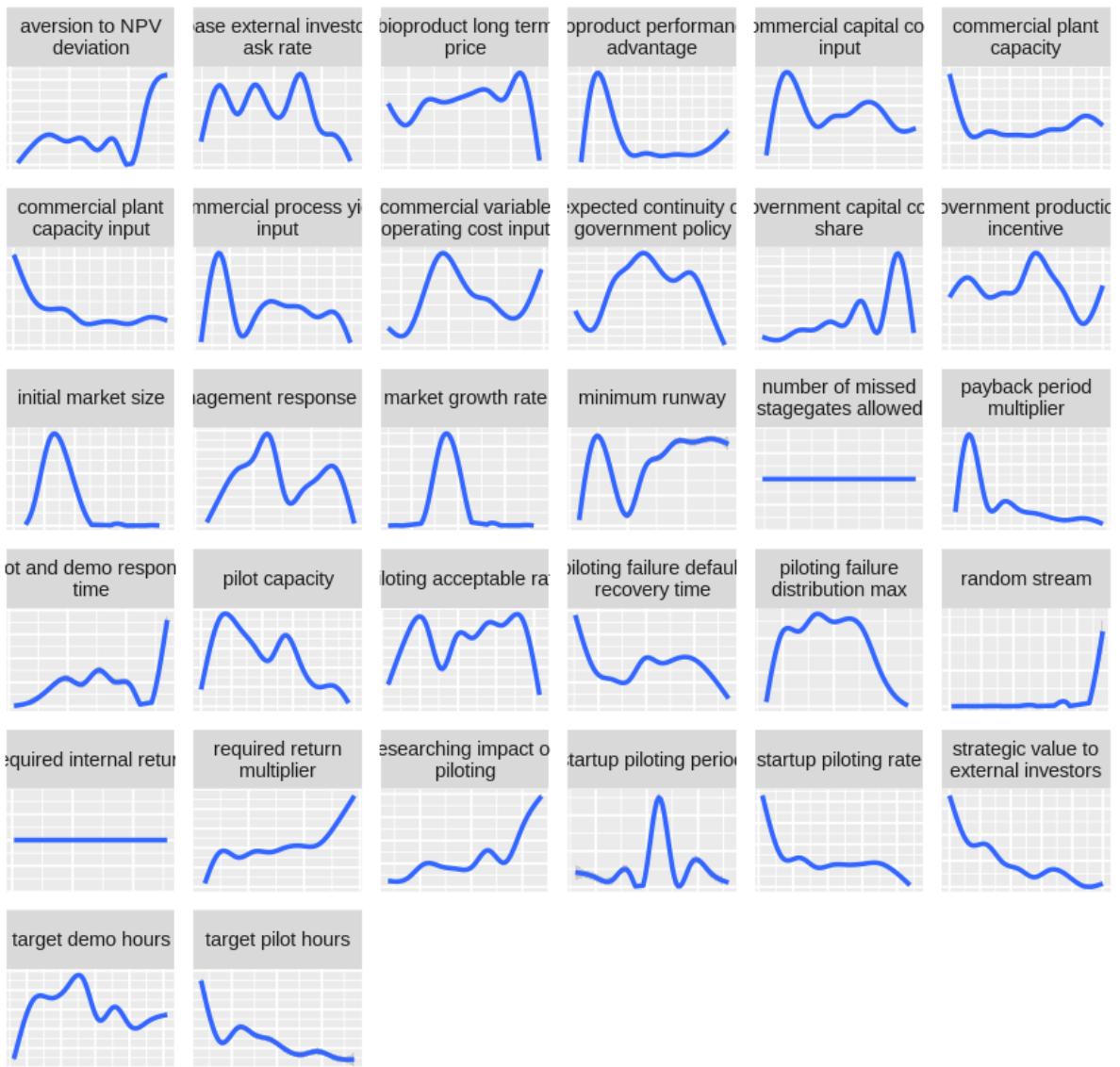
Variance-Based Sampling Density for Total Investment



Warning message:

"Removed 228 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for Working Capital

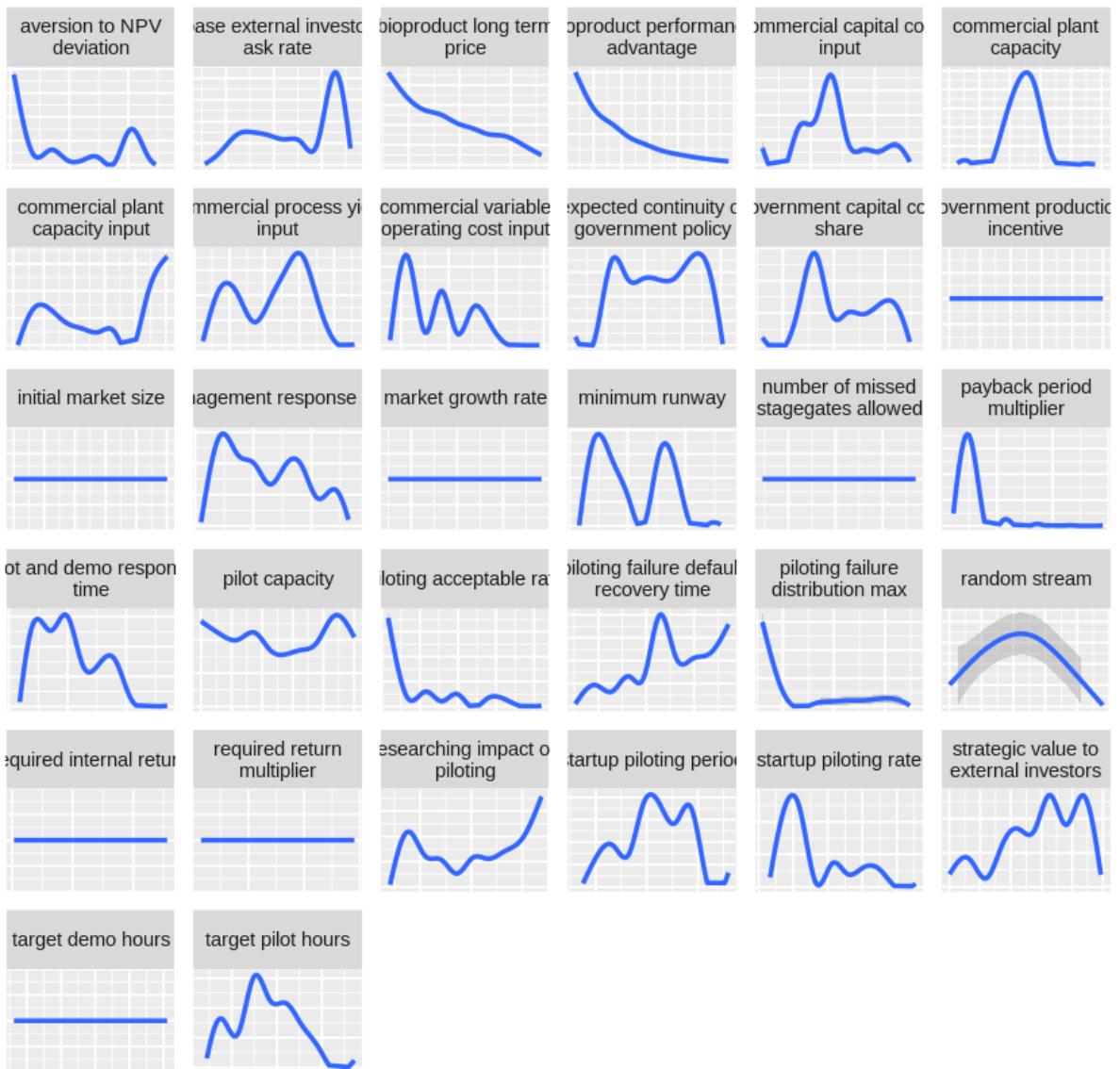


Warning message:

"Removed 829 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 221 rows containing missing values (geom_smooth)."

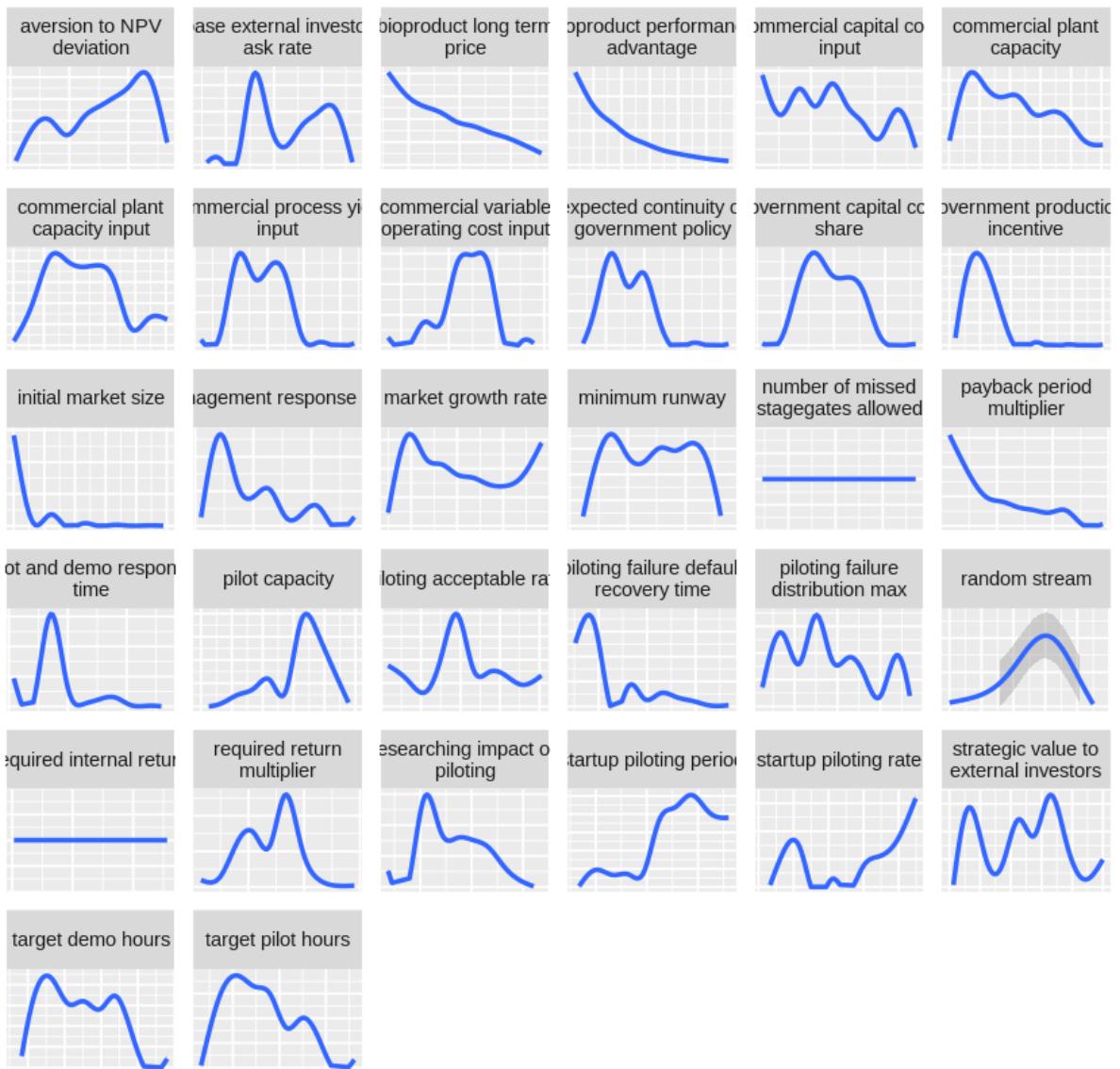
Variance-Based Sampling Density for bioproduct favorability indicator



Warning message:

"Removed 280 rows containing missing values (geom_smooth)."

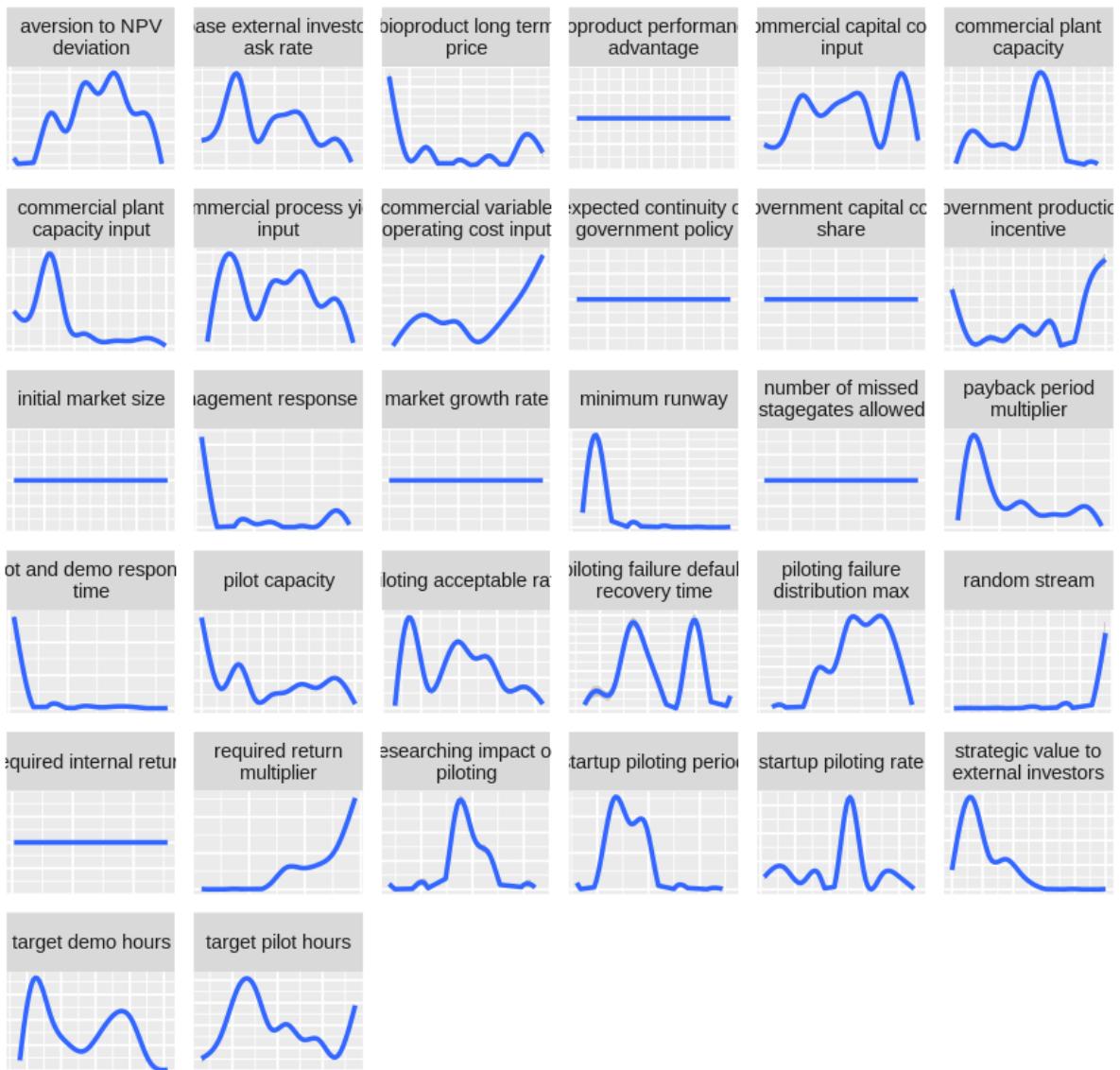
Variance-Based Sampling Density for bioproduct market share mass



Warning message:

"Removed 45 rows containing missing values (geom_smooth)."

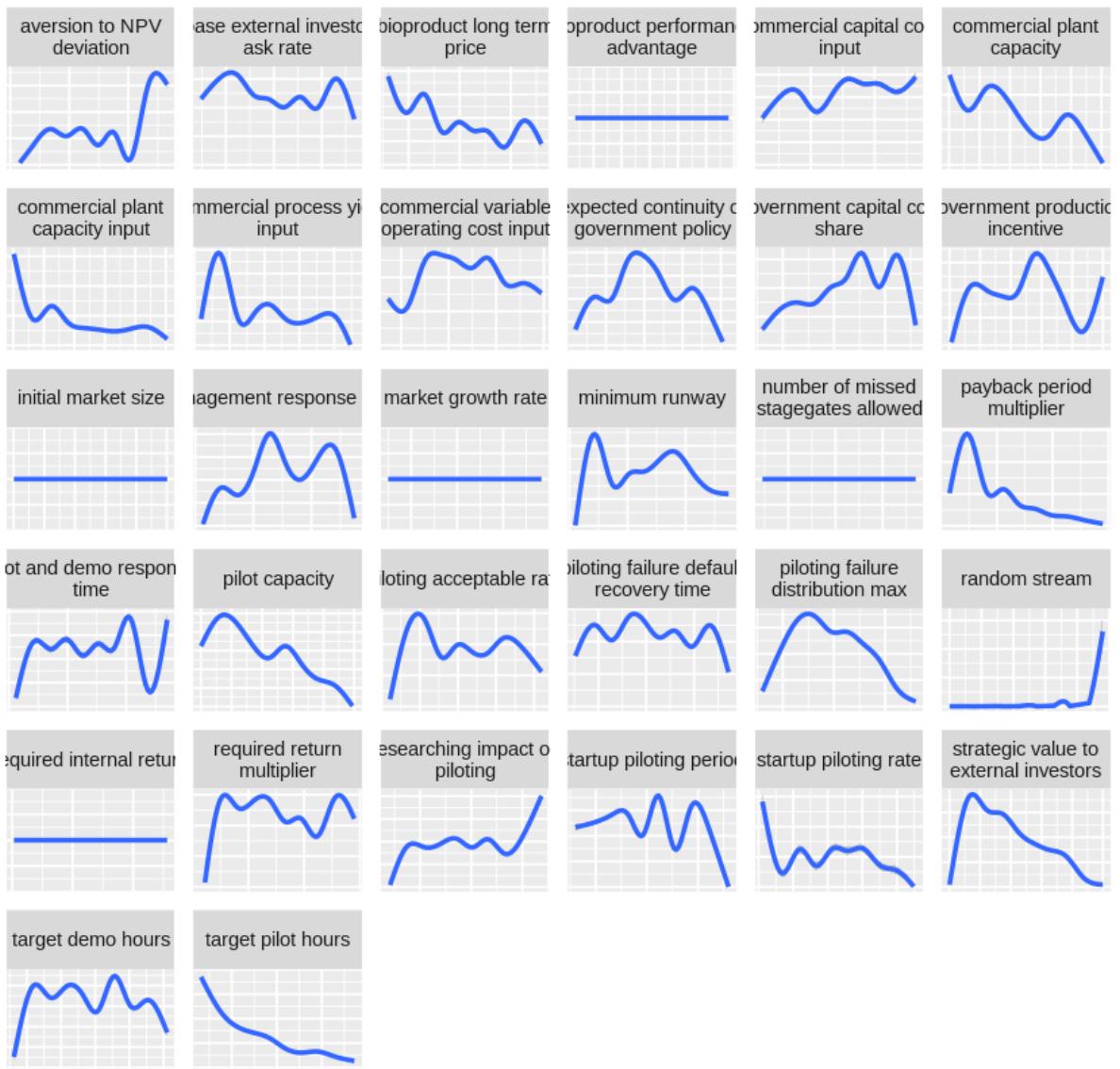
Variance-Based Sampling Density for commercial plant construction



Warning message:

"Removed 42 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for commercial plant is built

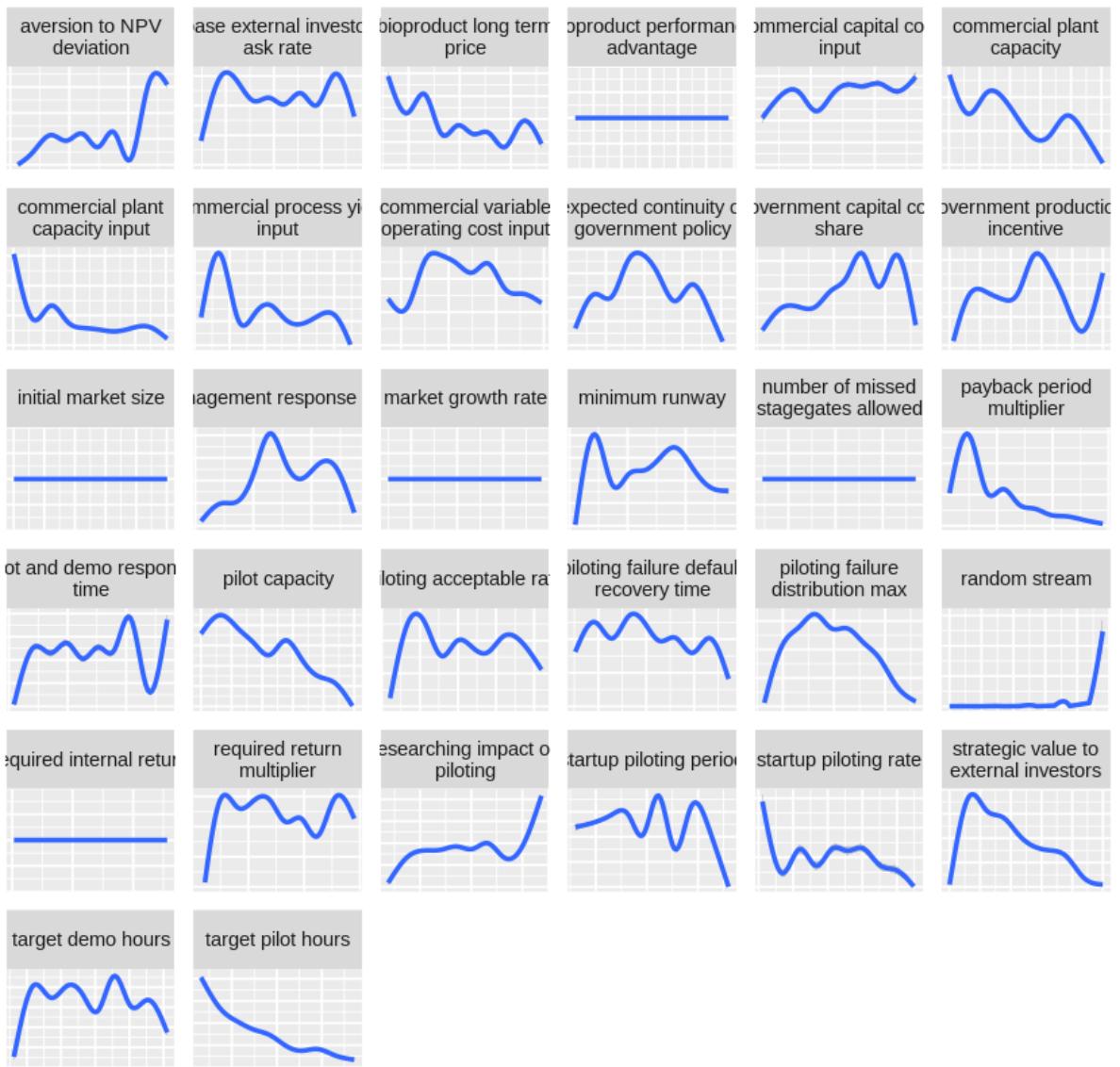


Warning message:

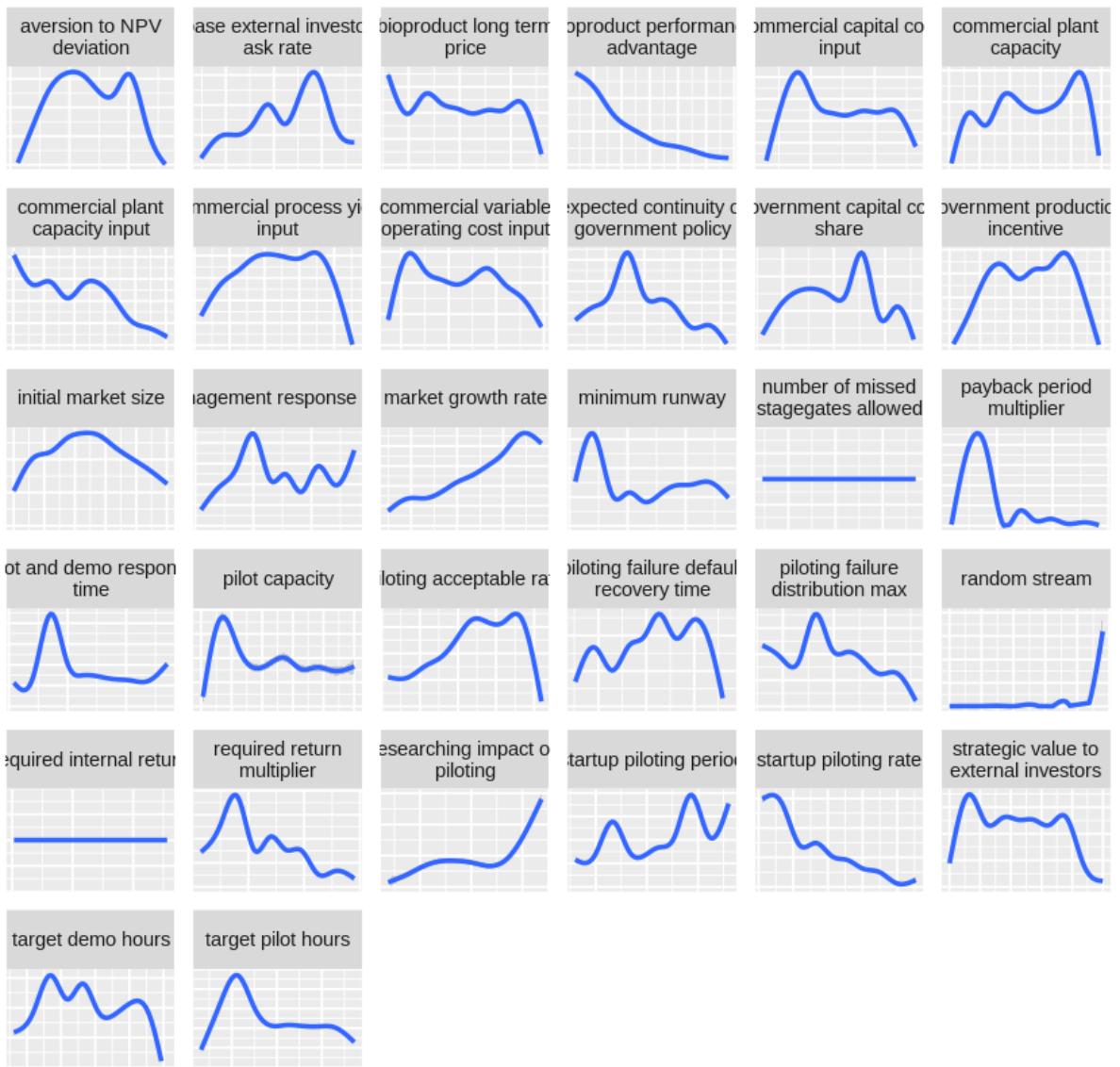
"Removed 15 rows containing non-finite values (stat_smooth)." "Warning me ssage:

"Removed 42 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for commercial plant operation



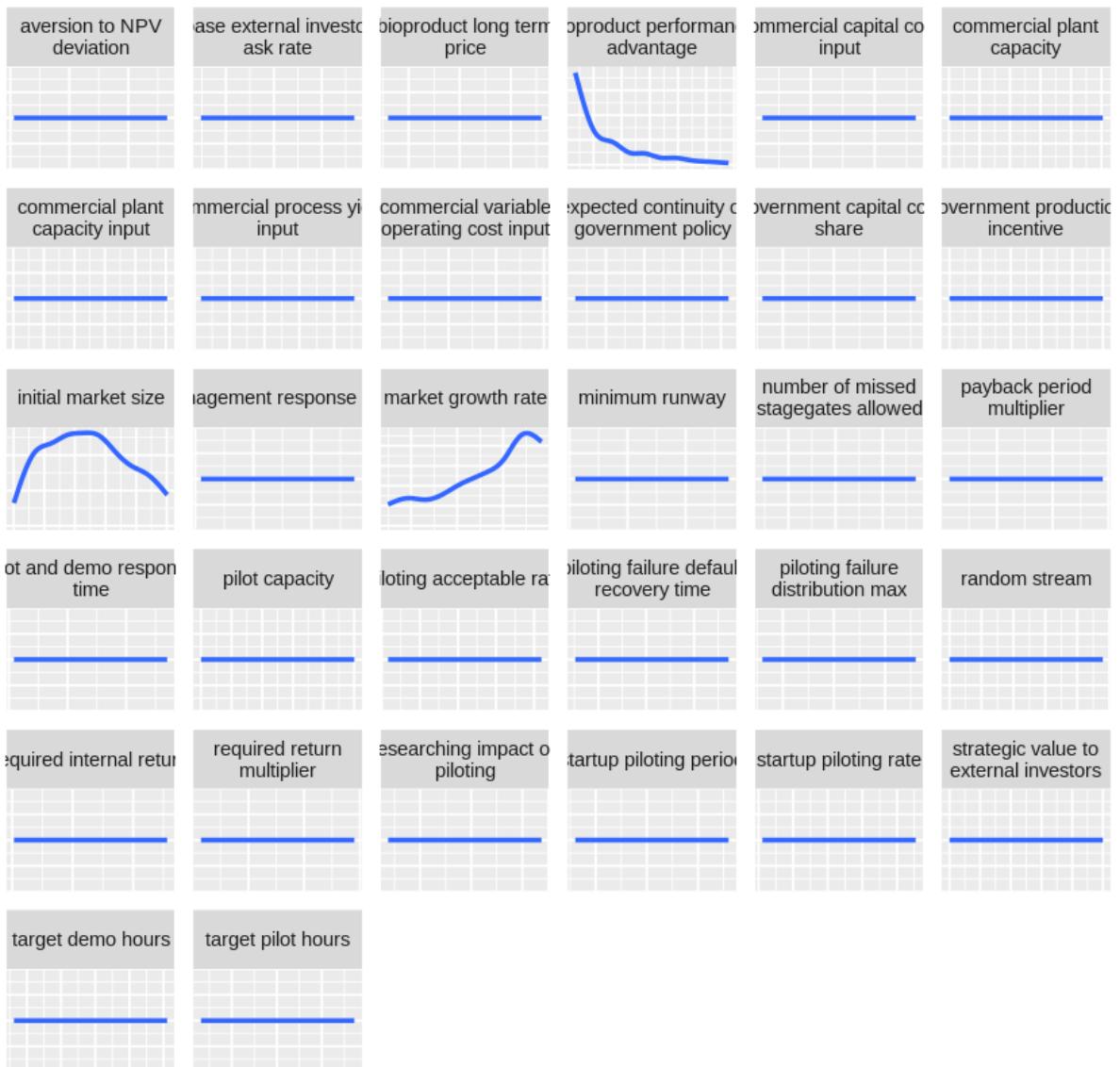
Variance-Based Sampling Density for current market size economic



Warning message:

"Removed 232 rows containing missing values (geom_smooth)."

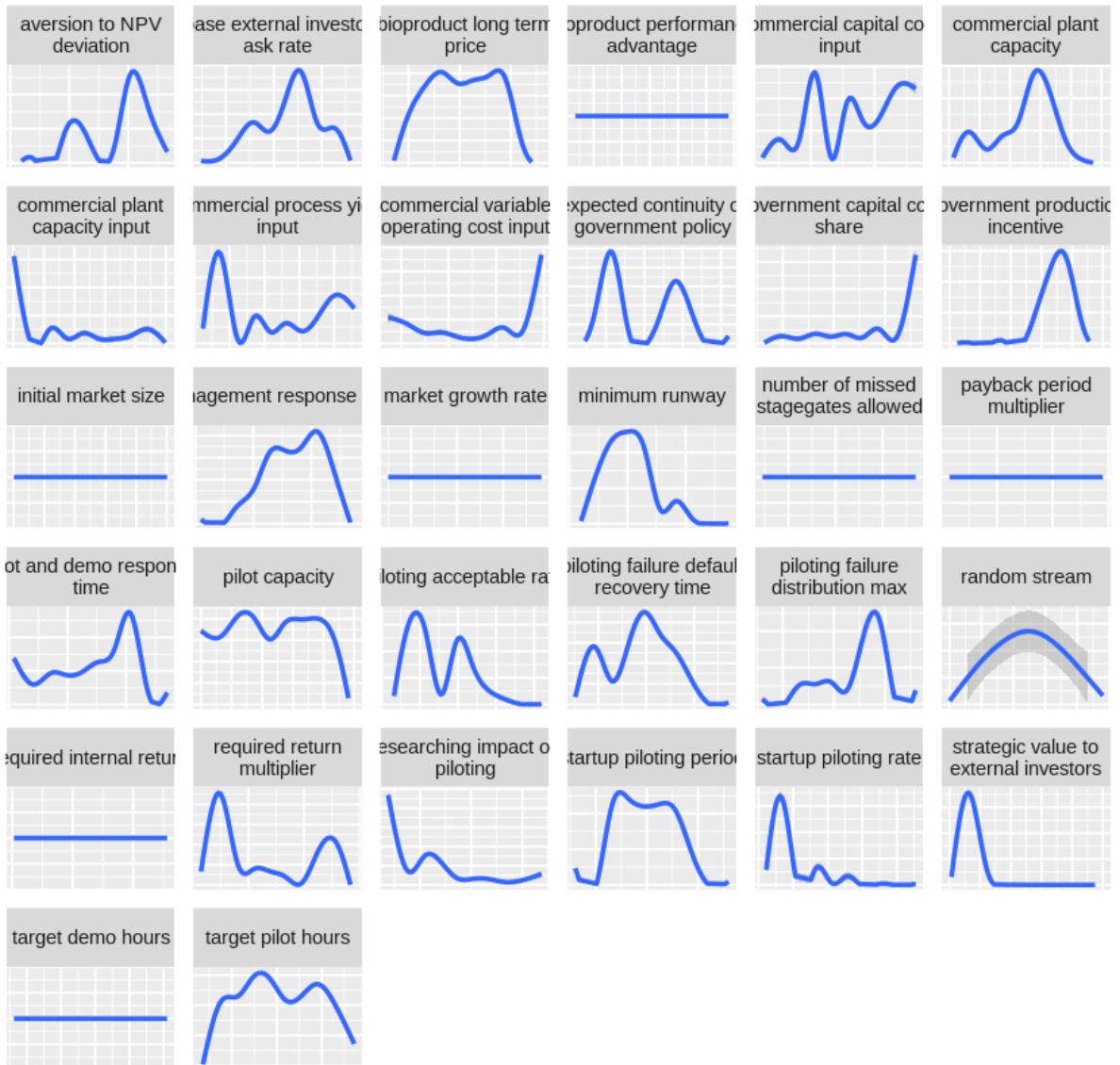
Variance-Based Sampling Density for current market size mass



Warning message:

"Removed 27 rows containing missing values (geom_smooth)."

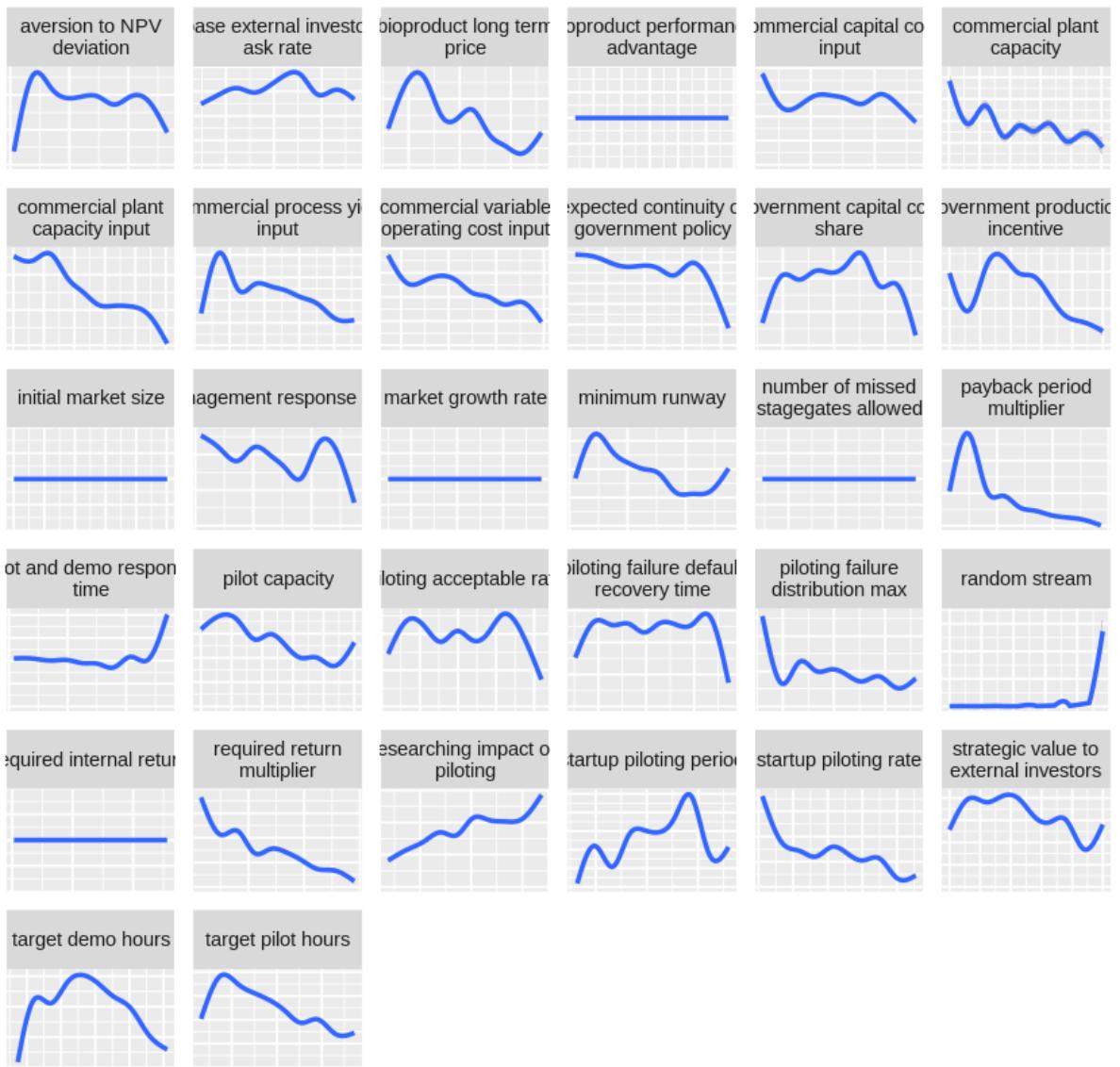
Variance-Based Sampling Density for demo plant construction



Warning message:

"Removed 29 rows containing missing values (geom_smooth)."

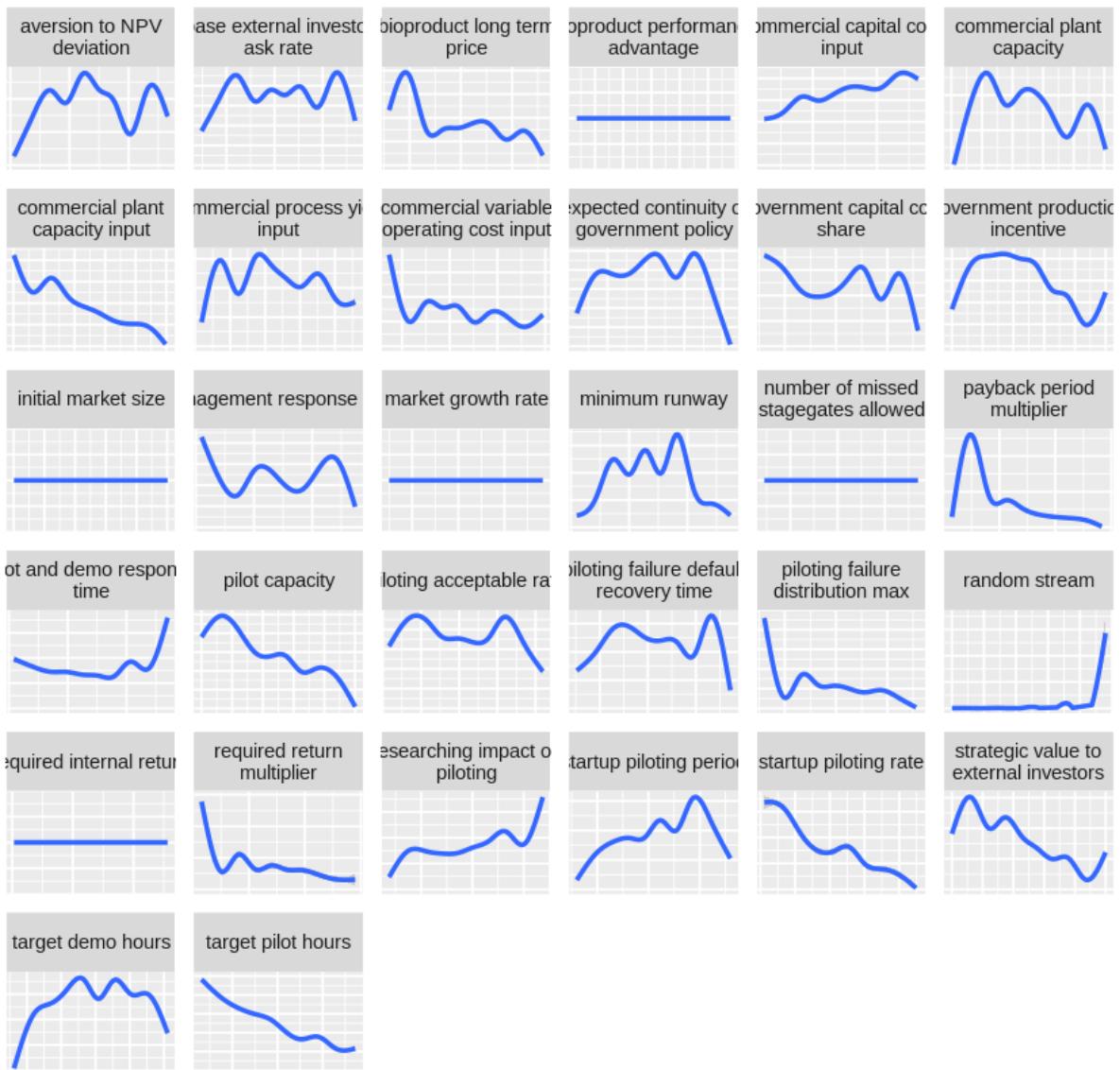
Variance-Based Sampling Density for demo plant is built



Warning message:

"Removed 26 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for demoing complete

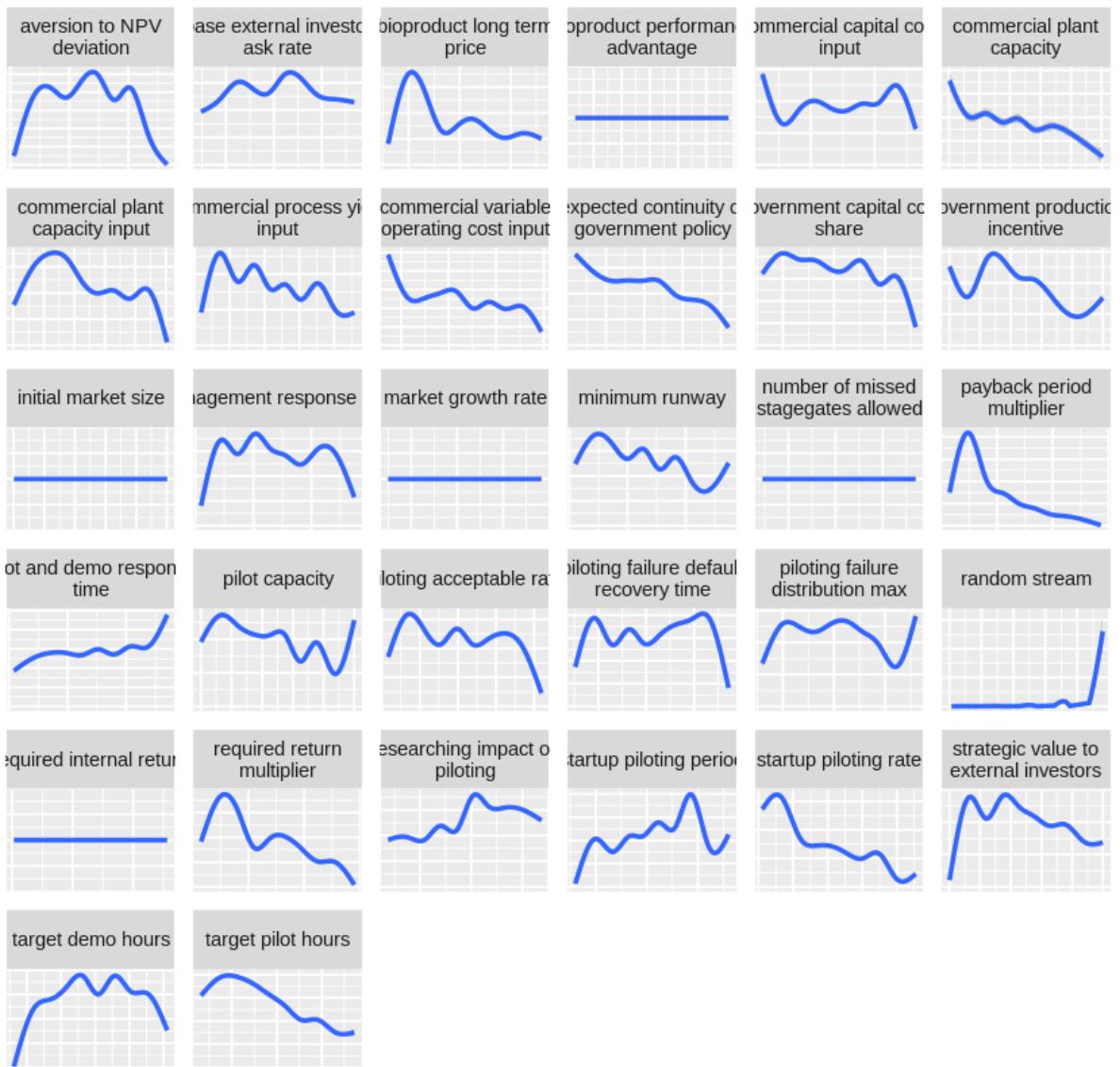


Warning message:

"Removed 169 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 26 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for demoing ongoing

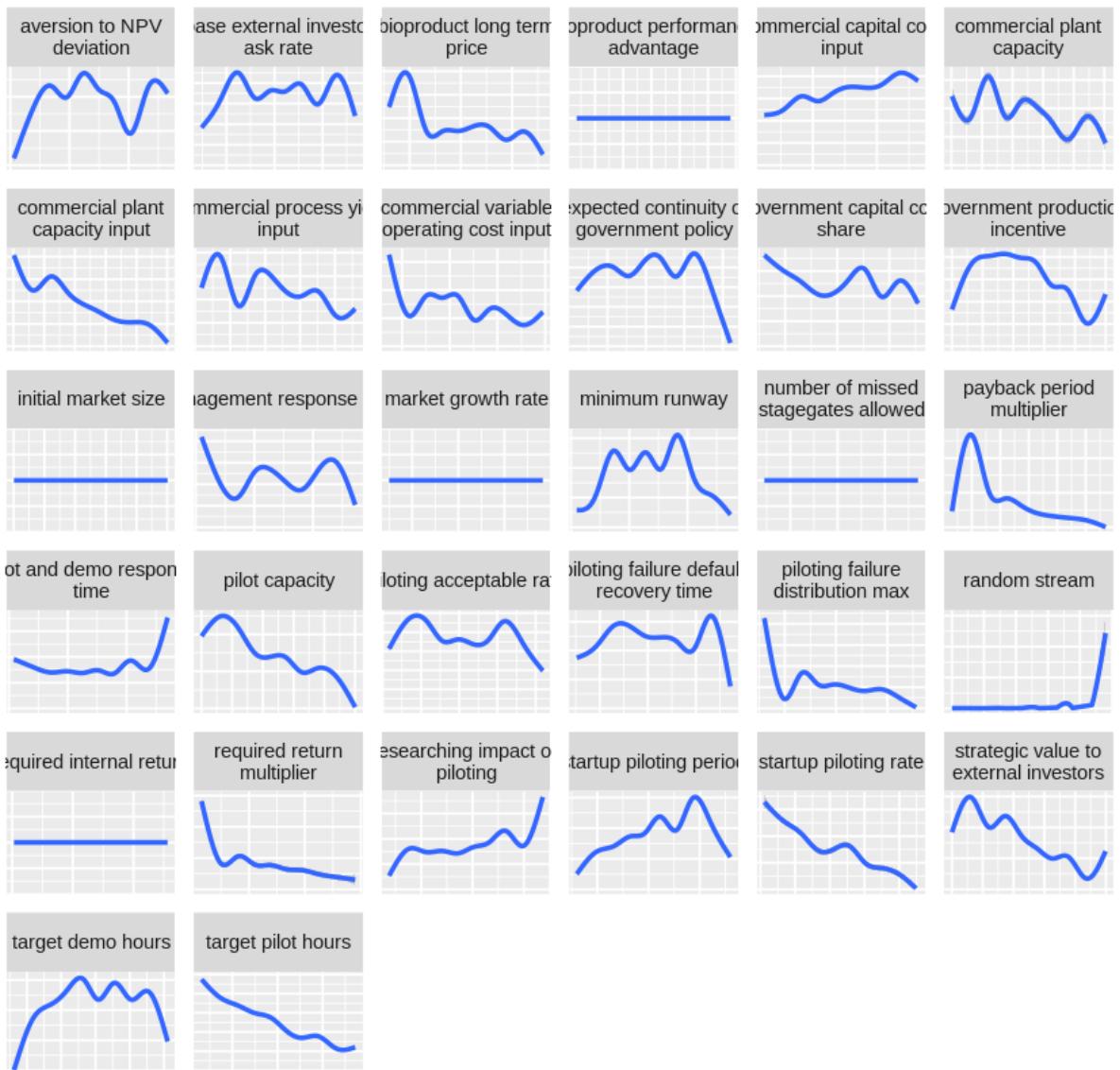


Warning message:

"Removed 96 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 106 rows containing missing values (geom_smooth)."

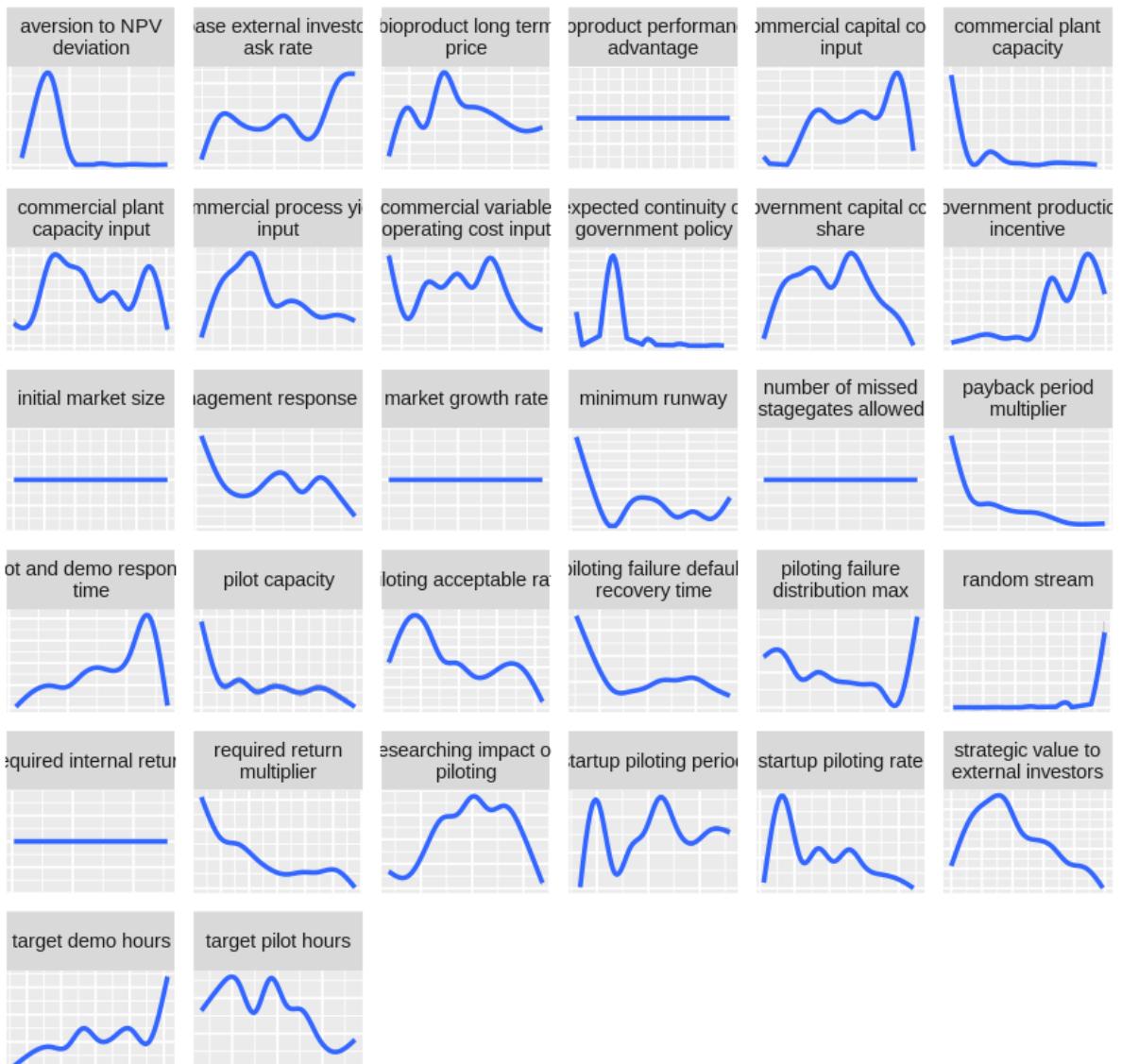
Variance-Based Sampling Density for demoing progress



Warning message:

"Removed 20 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for granting

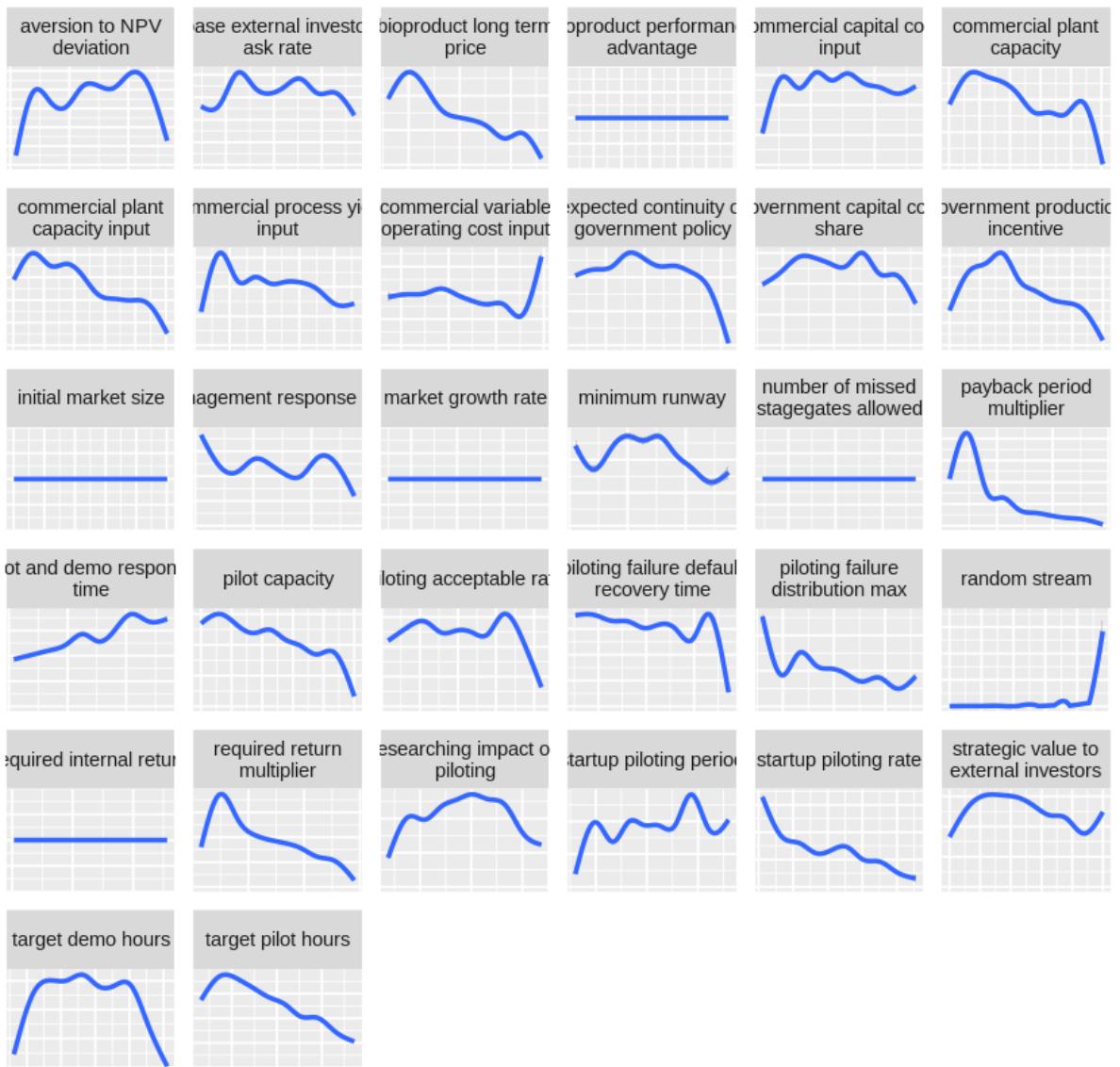


Warning message:

"Removed 46 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 89 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for in business indicator

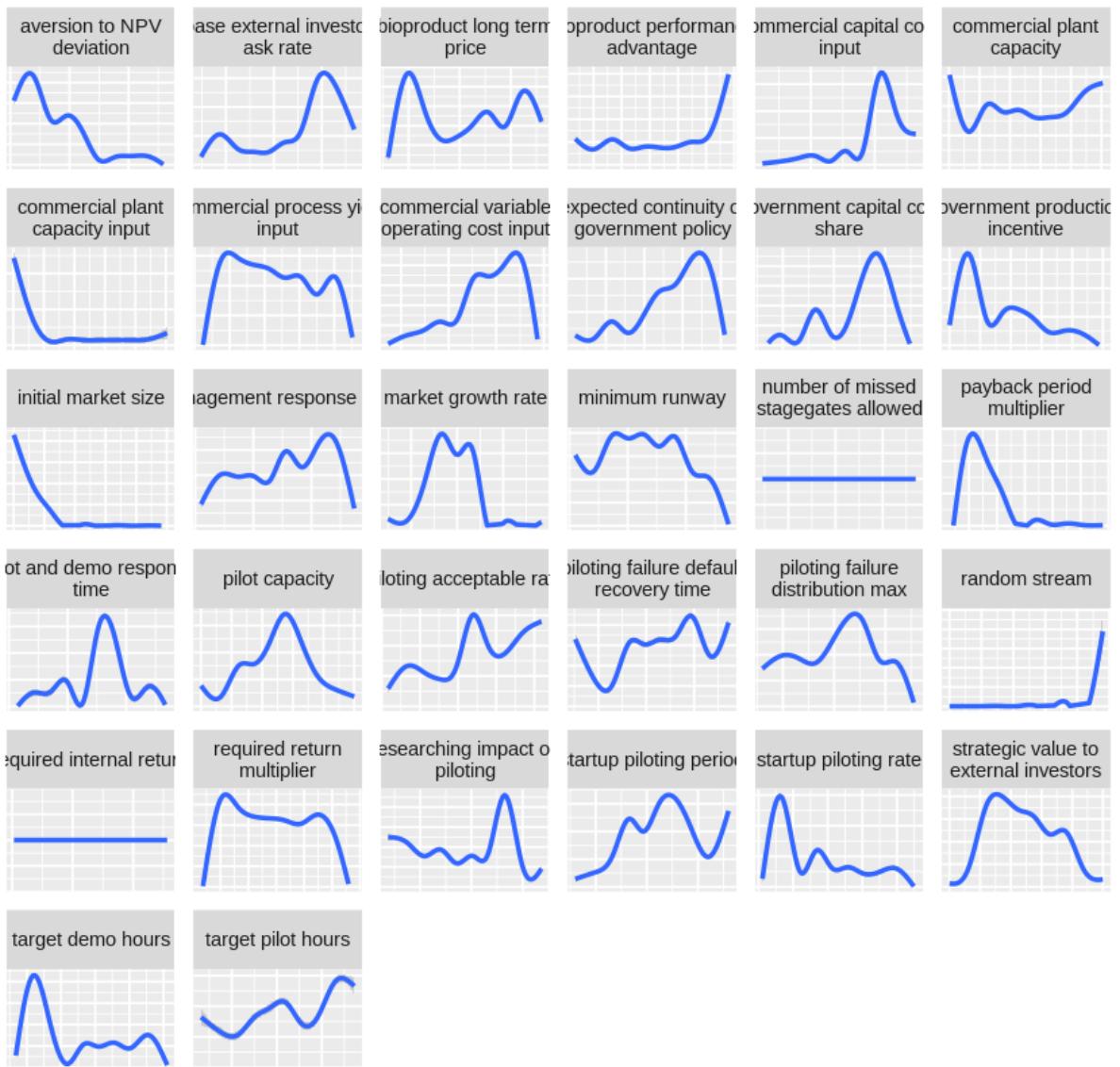


Warning message:

"Removed 117 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 80 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for investing

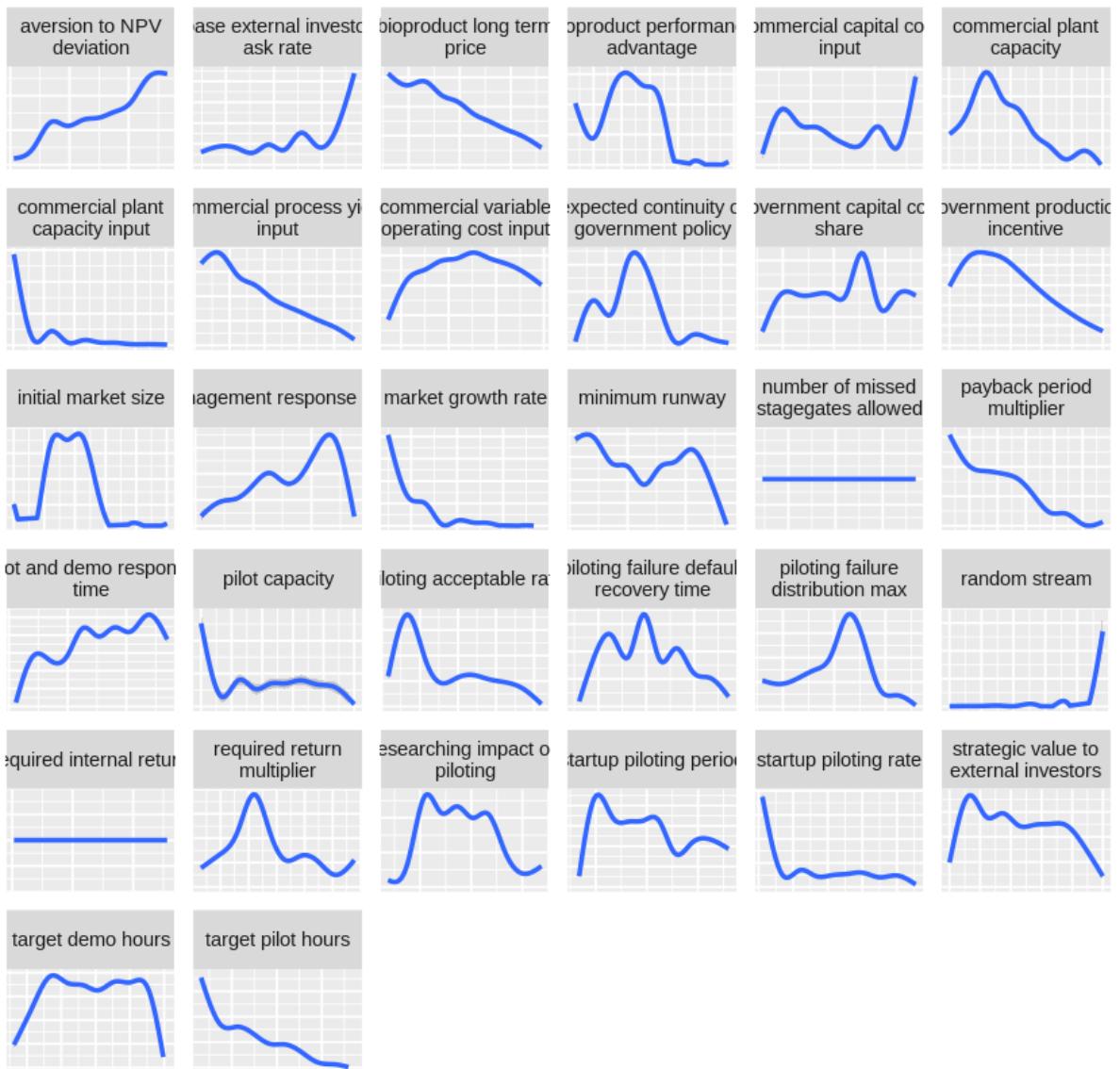


Warning message:

"Removed 149 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 268 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for long term market share

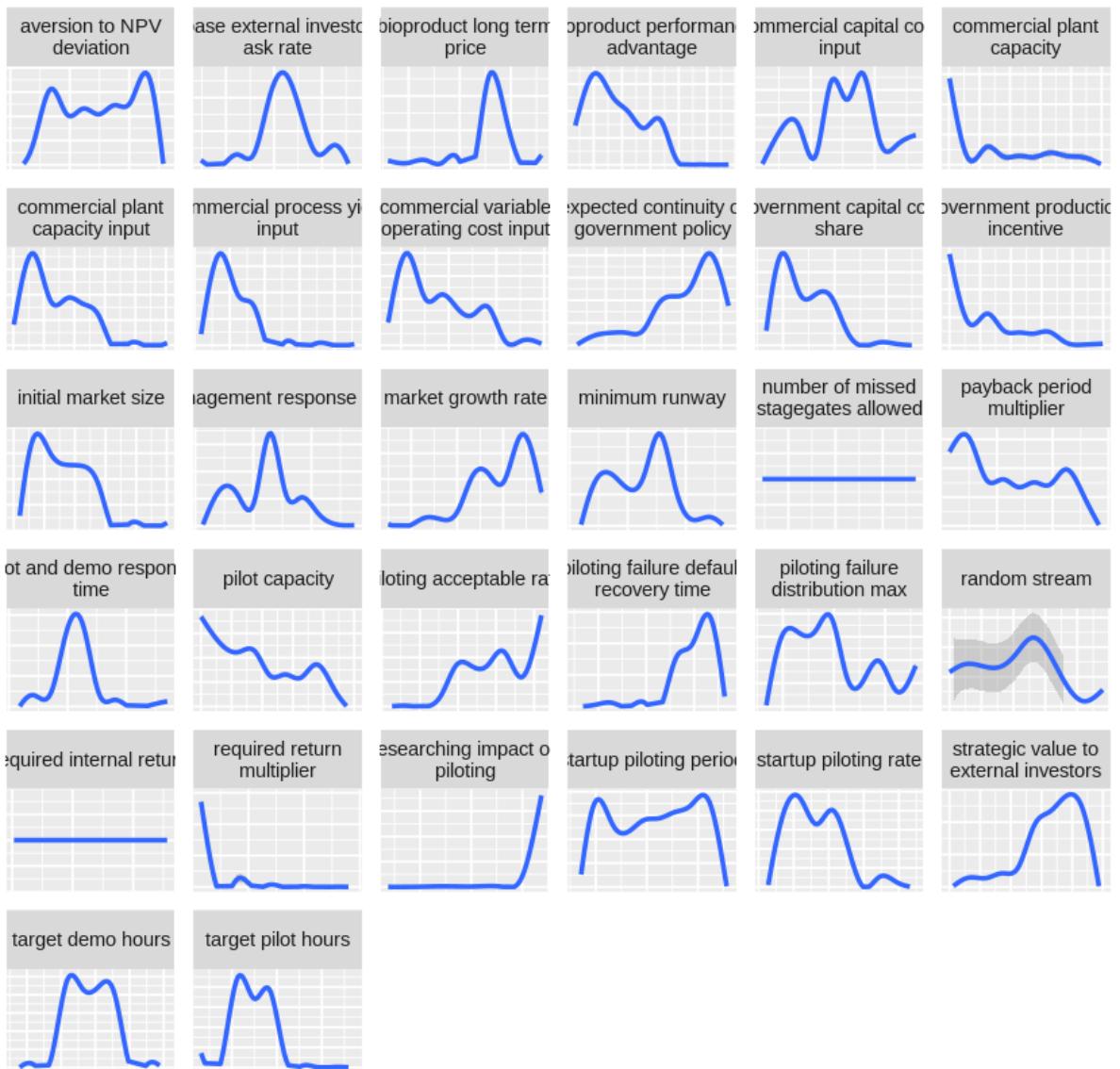


Warning message:

"Removed 218 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 89 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for long term market value

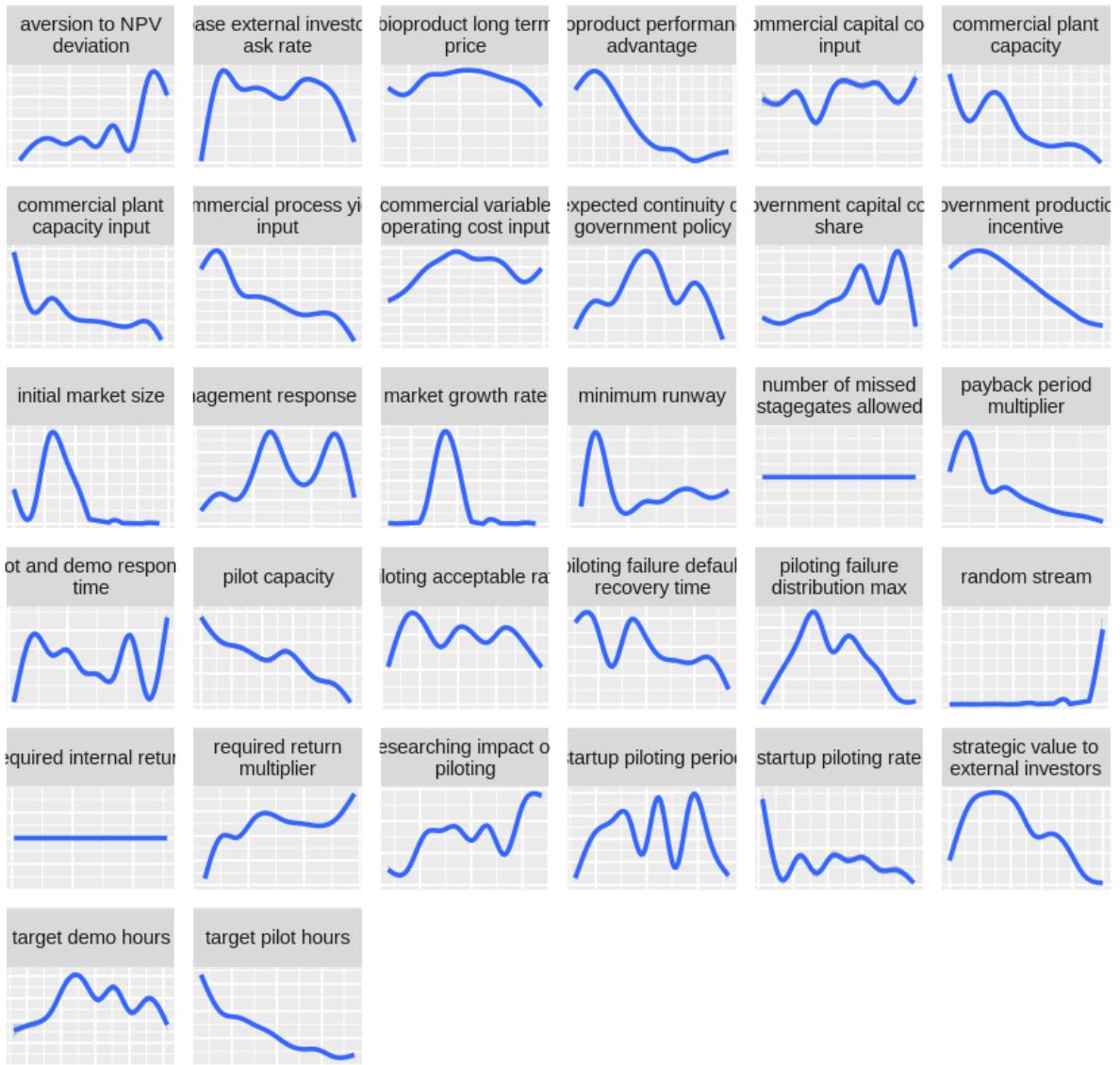


Warning message:

"Removed 30 rows containing non-finite values (stat_smooth)."
"Warning message:

"Removed 410 rows containing missing values (geom_smooth)."

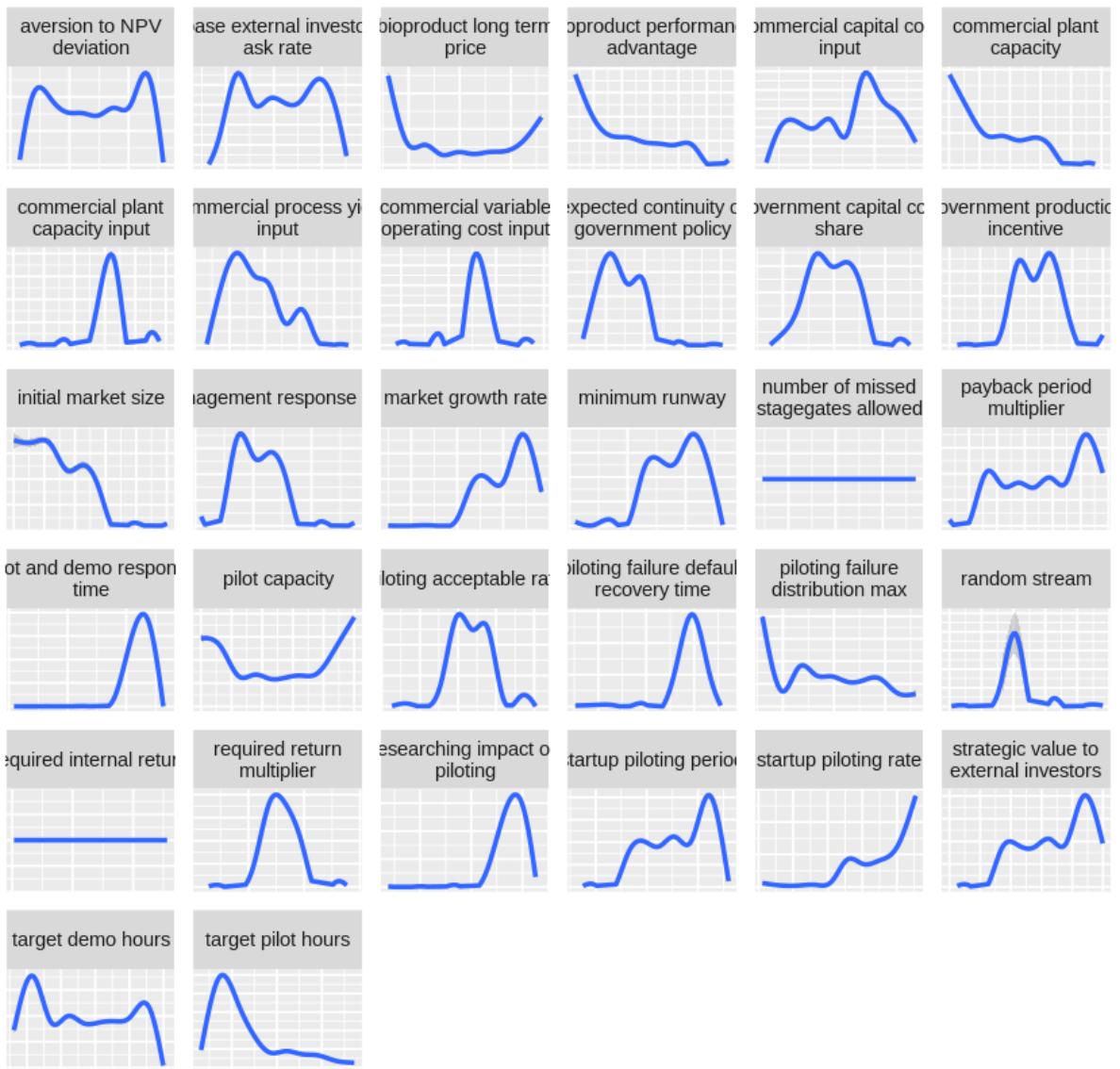
Variance-Based Sampling Density for long term selling price without green premium af



Warning message:

"Removed 170 rows containing missing values (geom_smooth)."

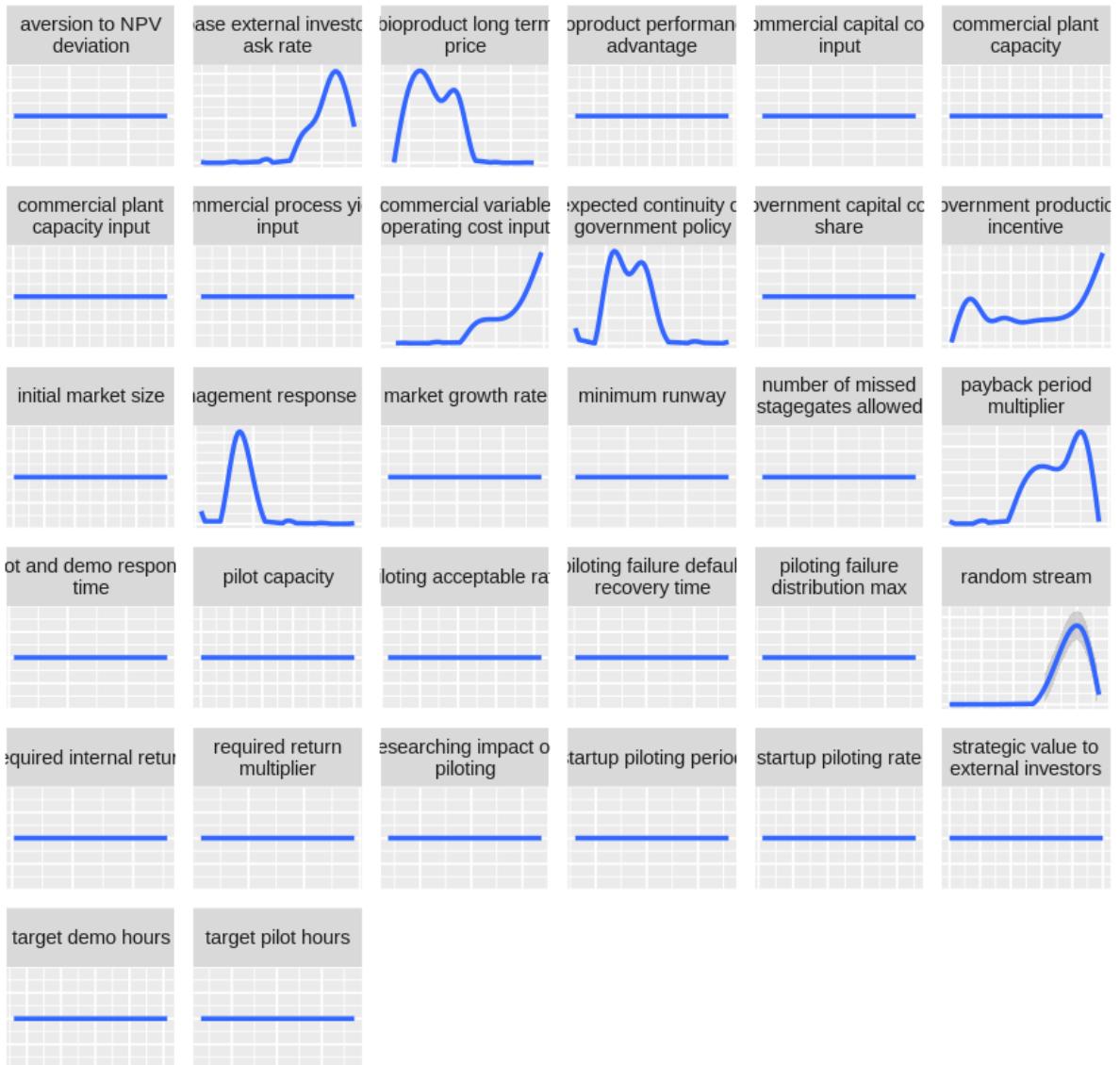
Variance-Based Sampling Density for payback period



Warning message:

"Removed 87 rows containing missing values (geom_smooth)."

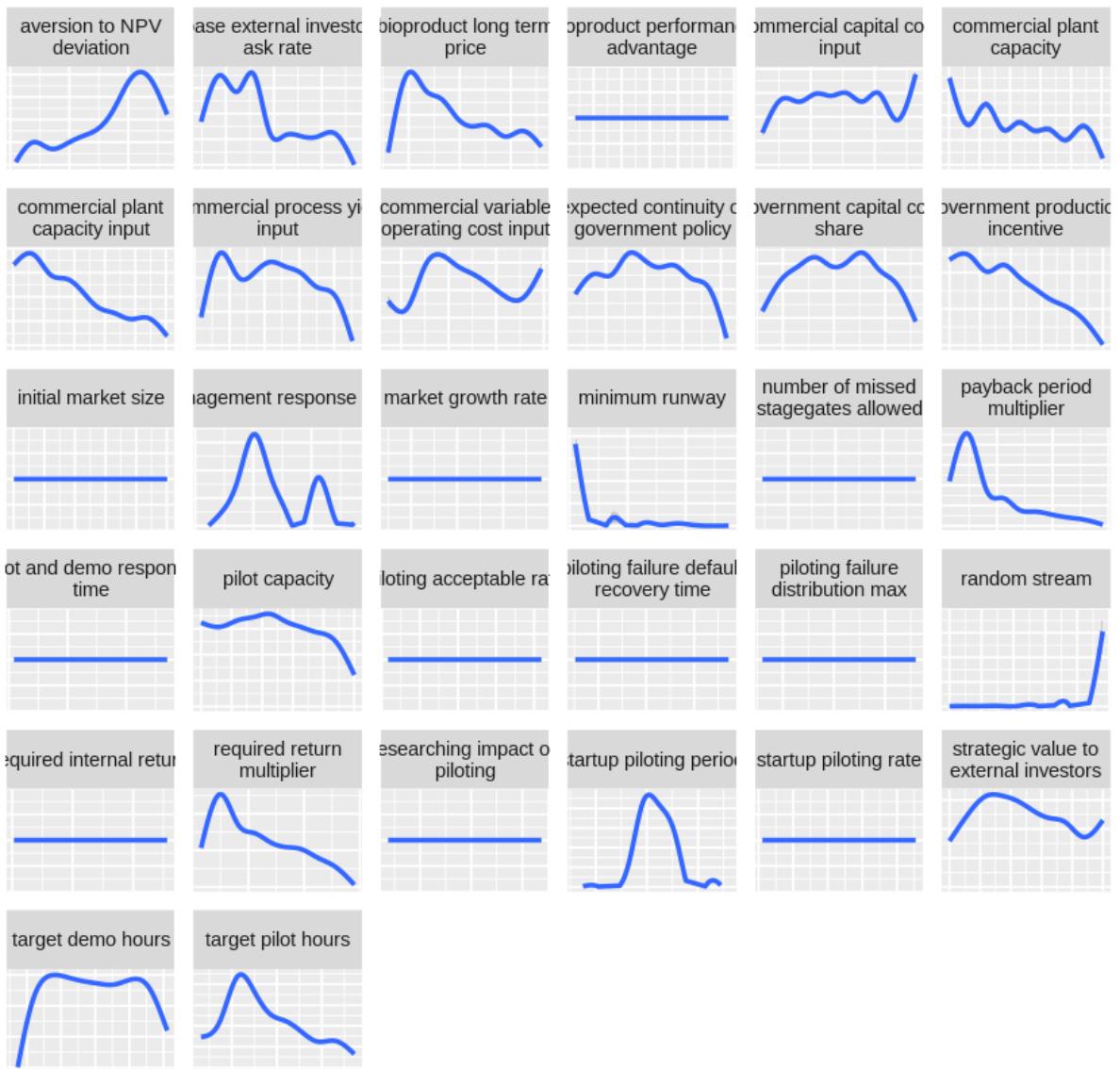
Variance-Based Sampling Density for pilot plant construction



Warning message:

"Removed 29 rows containing missing values (geom_smooth)."

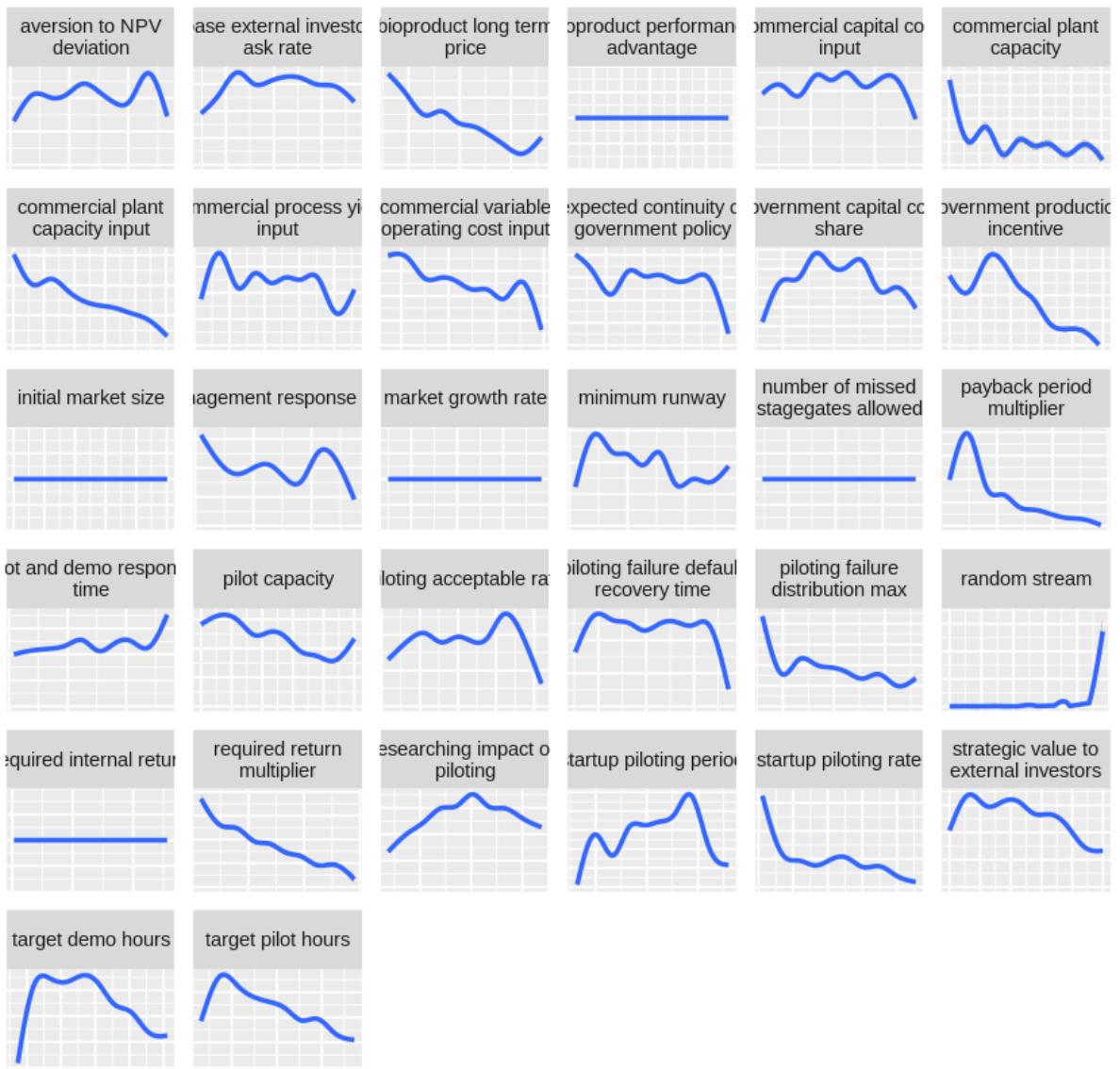
Variance-Based Sampling Density for pilot plant is built



Warning message:

"Removed 23 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for piloting complete

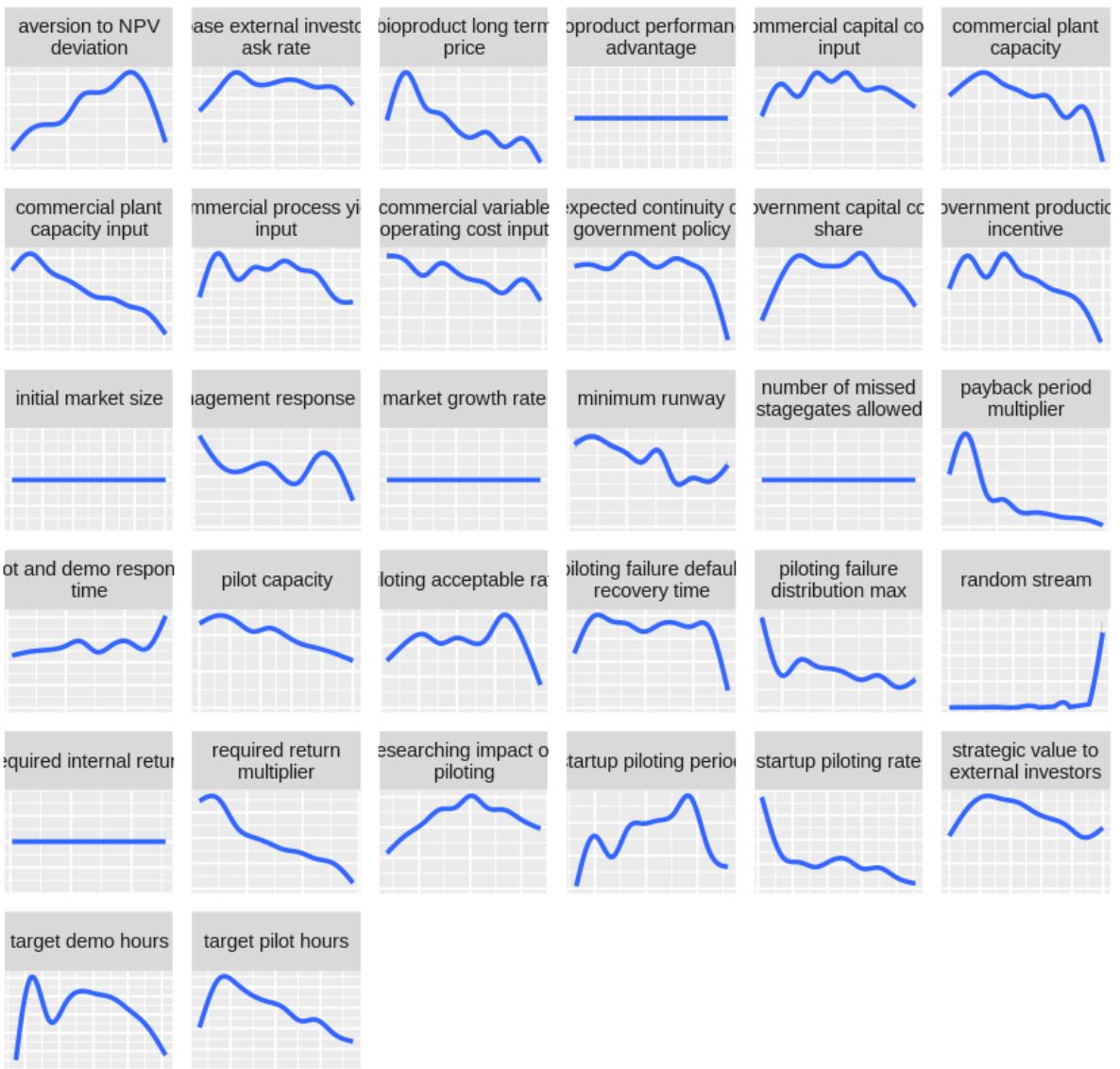


Warning message:

"Removed 4 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 29 rows containing missing values (geom_smooth)."

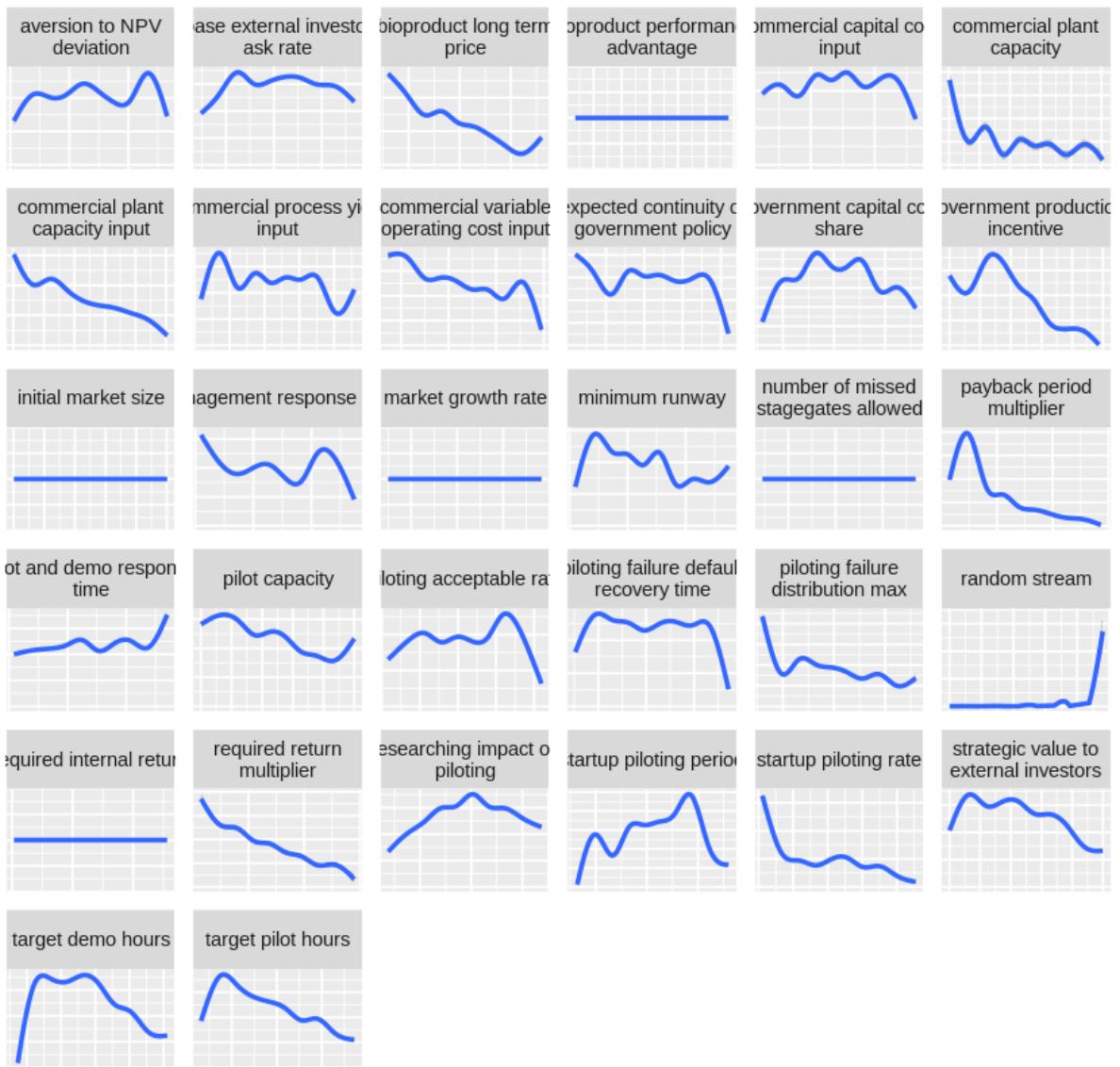
Variance-Based Sampling Density for piloting ongoing



Warning message:

"Removed 24 rows containing missing values (geom_smooth)."

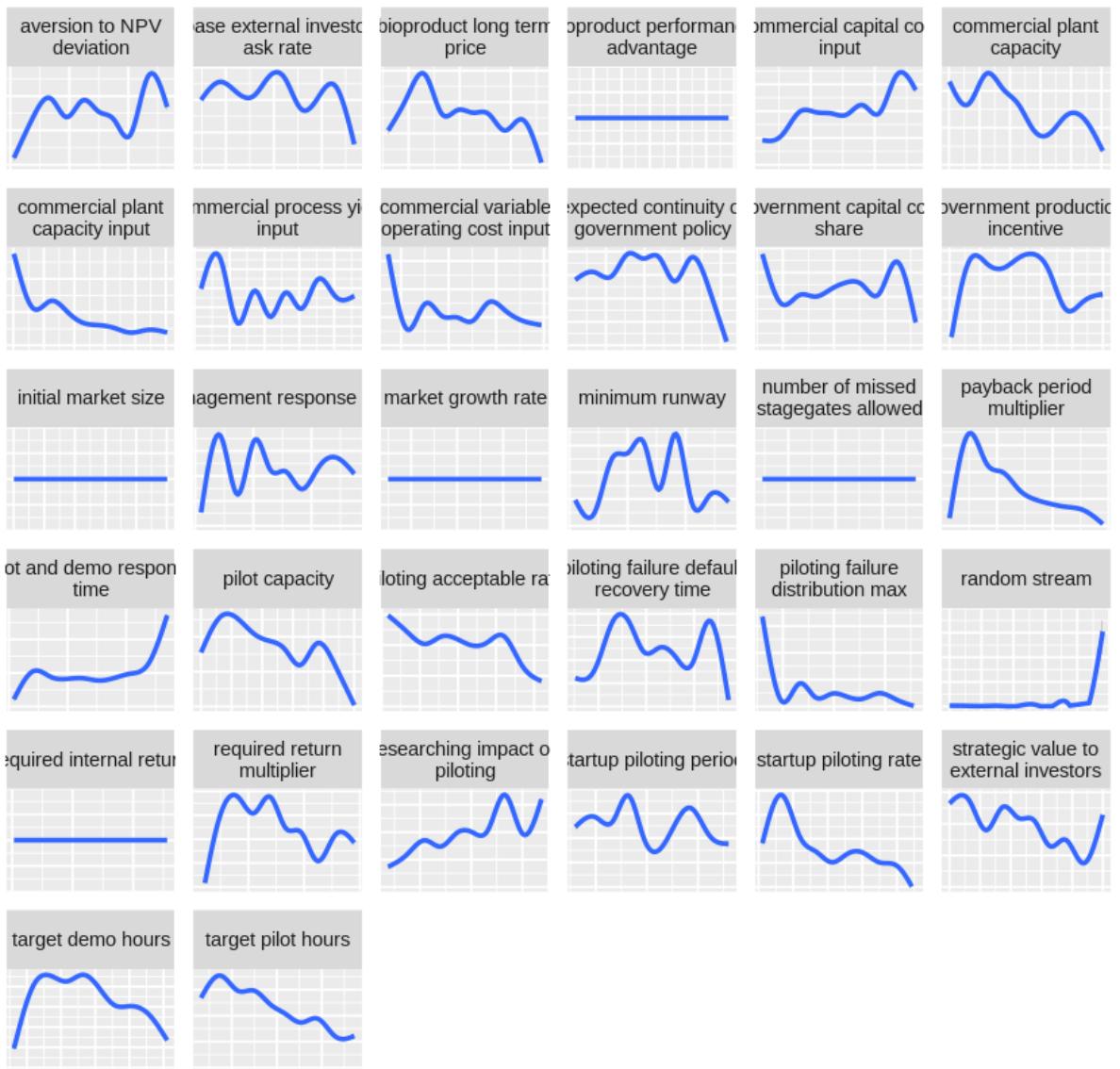
Variance-Based Sampling Density for piloting progress



Warning message:

"Removed 54 rows containing missing values (geom_smooth)."

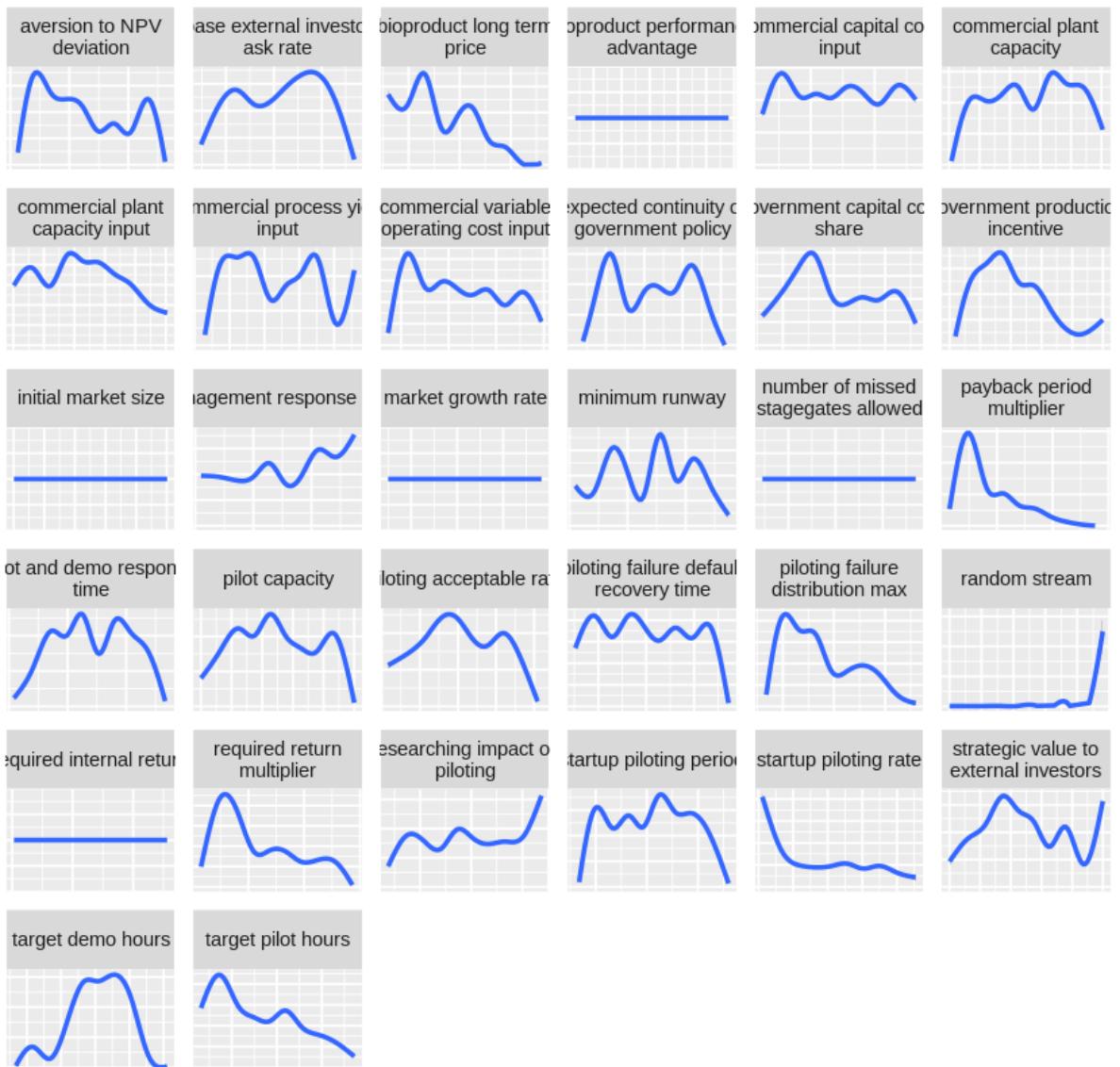
Variance-Based Sampling Density for precommercial



Warning message:

"Removed 90 rows containing missing values (geom_smooth)."

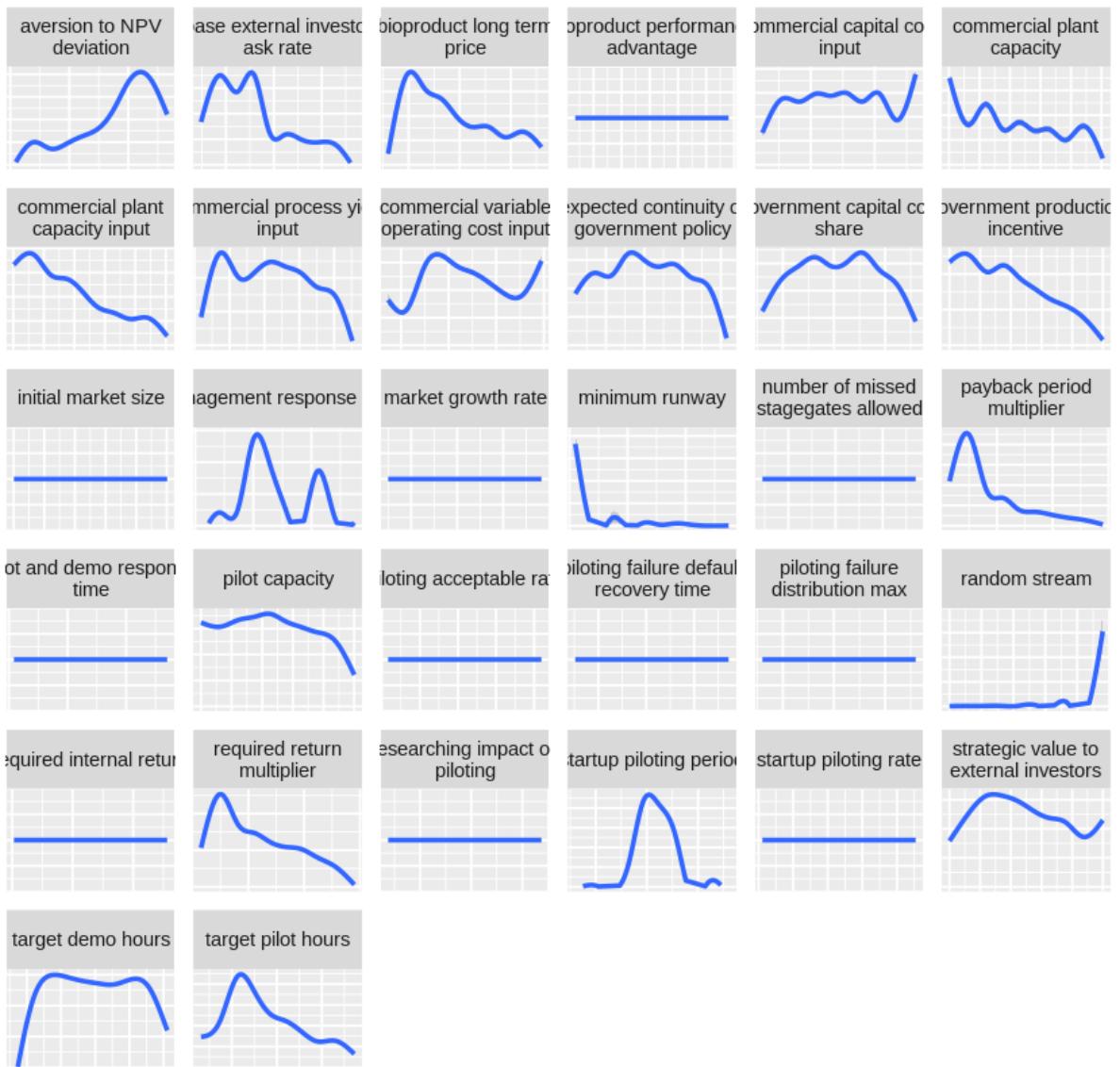
Variance-Based Sampling Density for predemoing



Warning message:

"Removed 229 rows containing missing values (geom_smooth)."

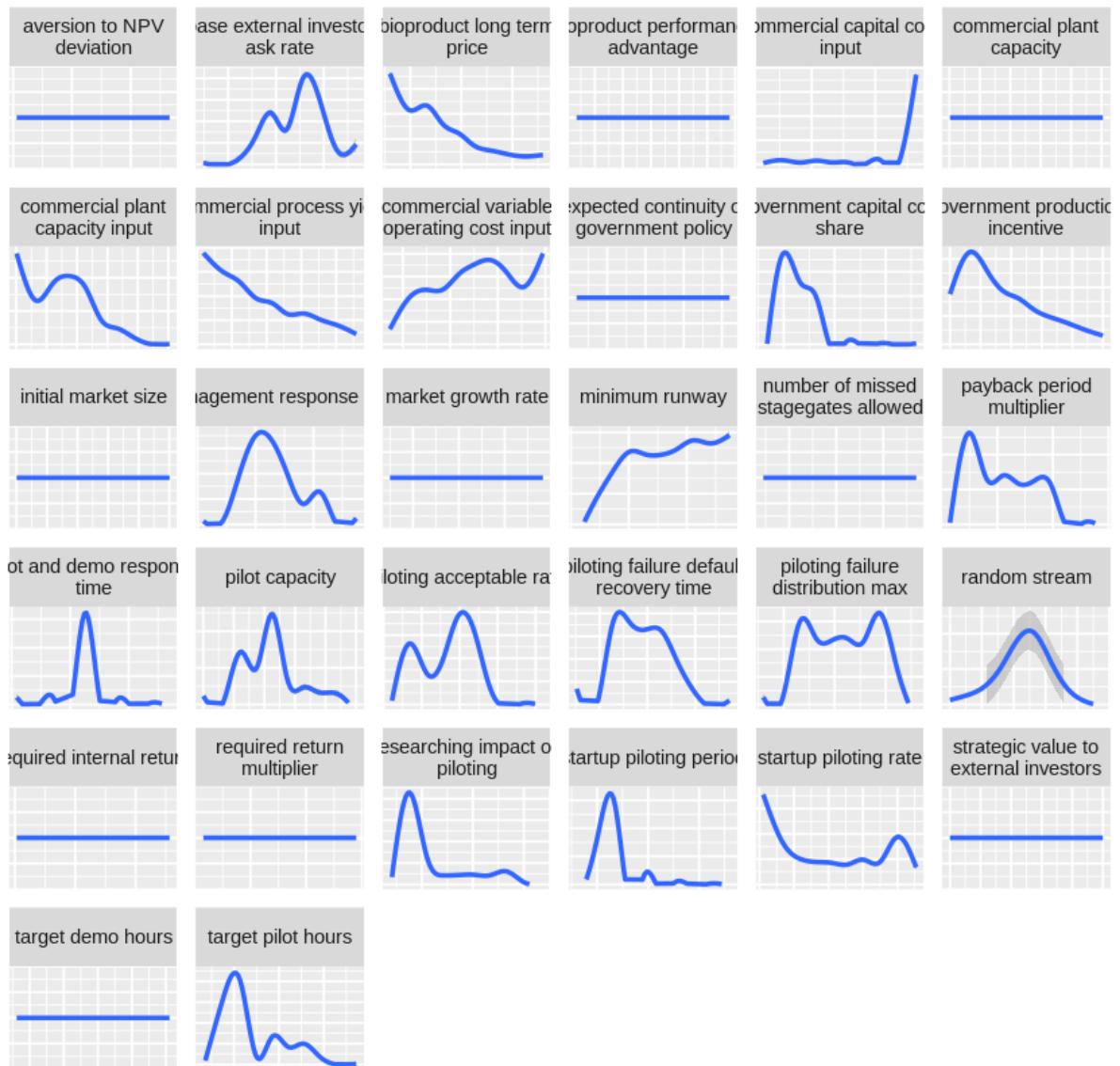
Variance-Based Sampling Density for prepiloting



Warning message:

"Removed 289 rows containing missing values (geom_smooth)."

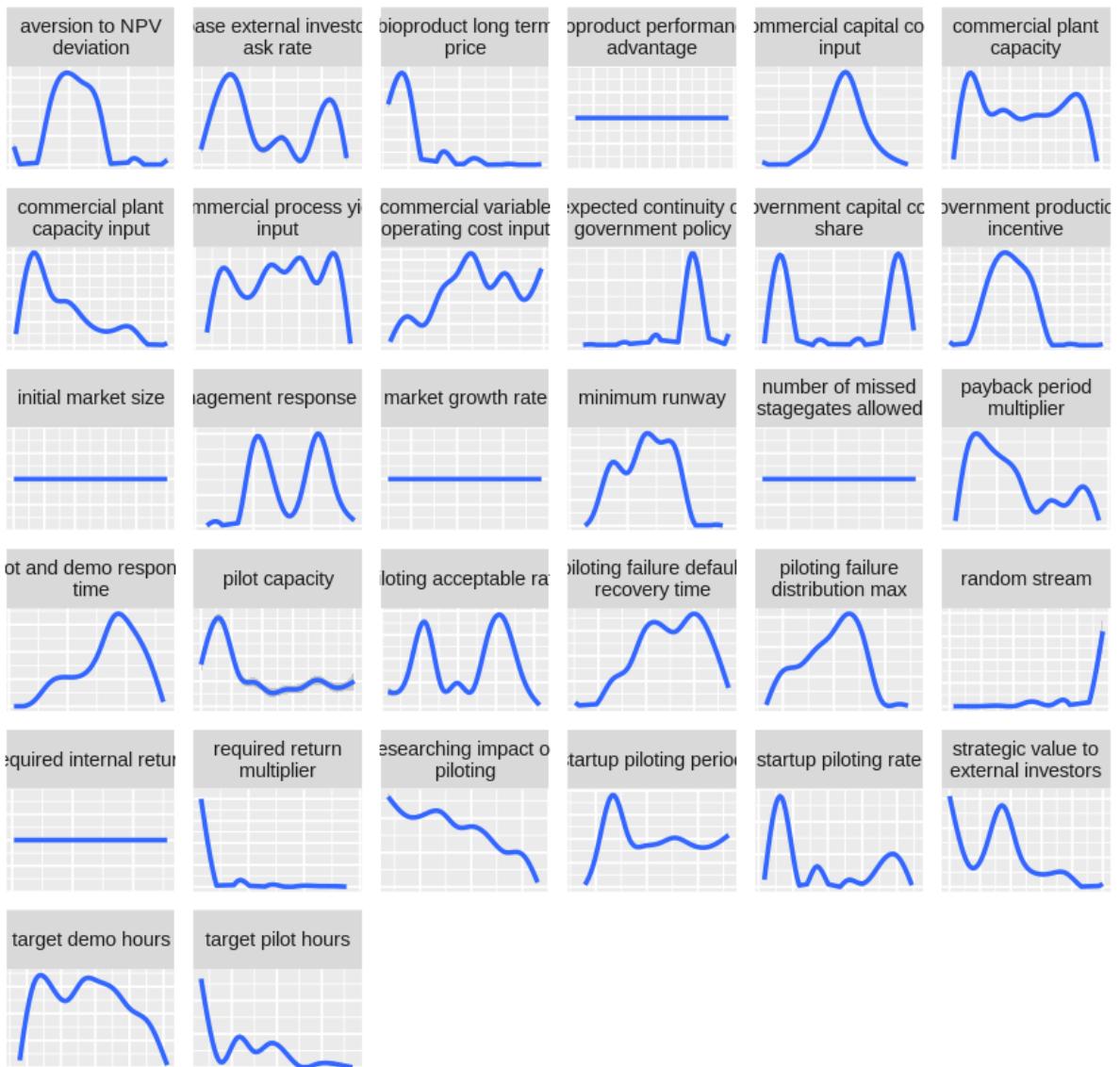
Variance-Based Sampling Density for profitability indicator



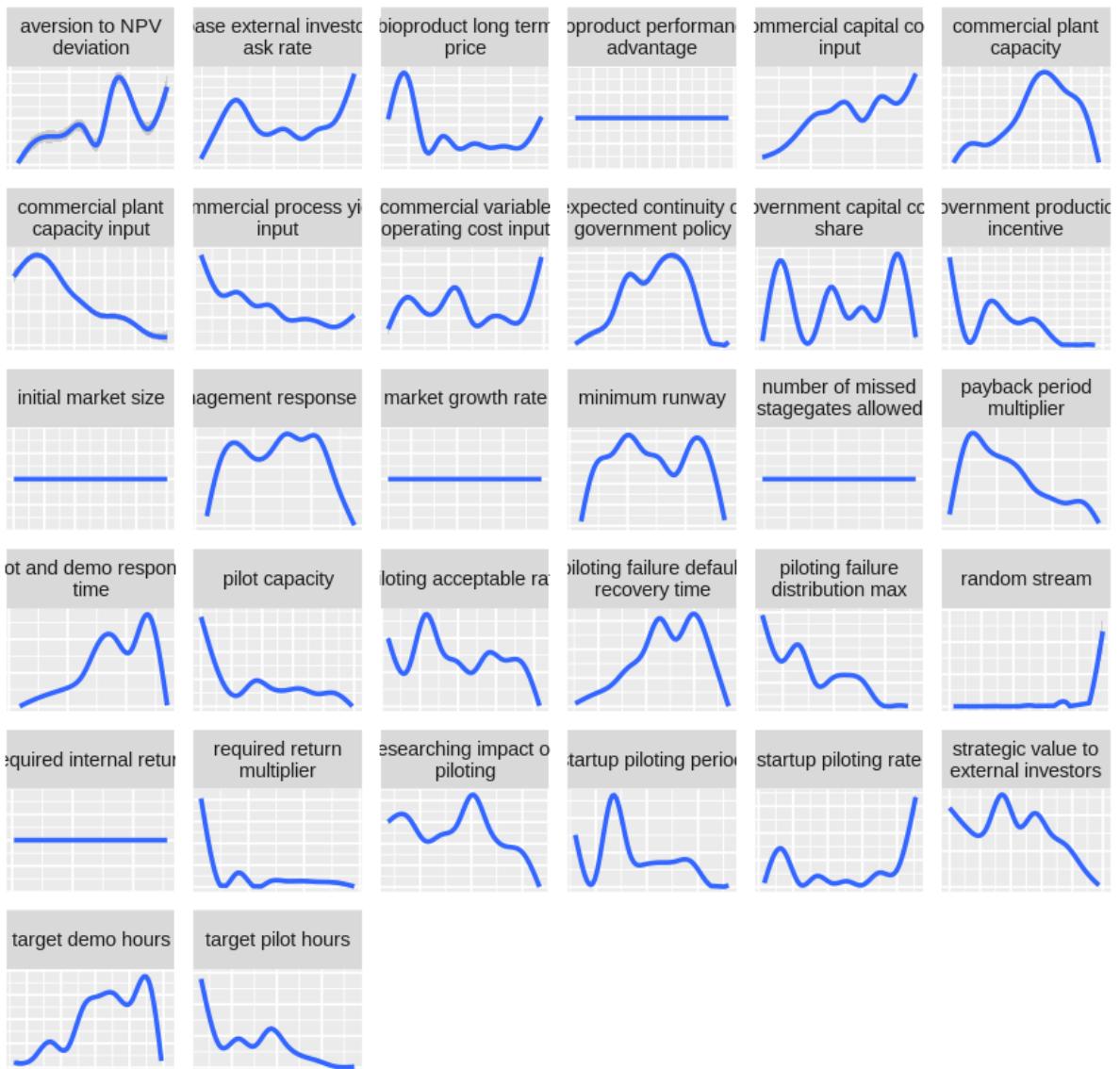
Warning message:

"Removed 99 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for regulatory delay



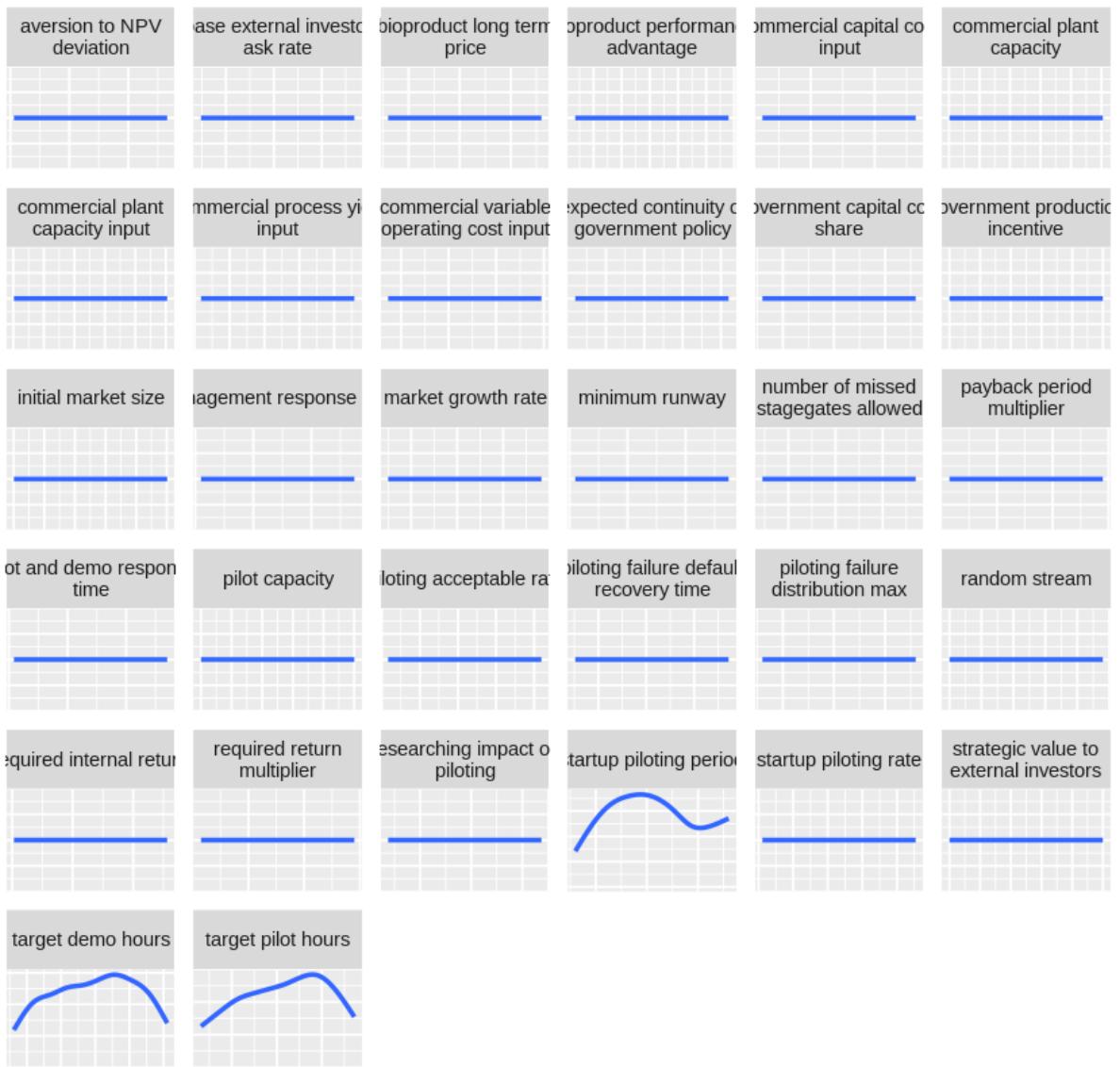
Variance-Based Sampling Density for regulatory process ongoing



Warning message:

"Removed 28 rows containing missing values (geom_smooth)."

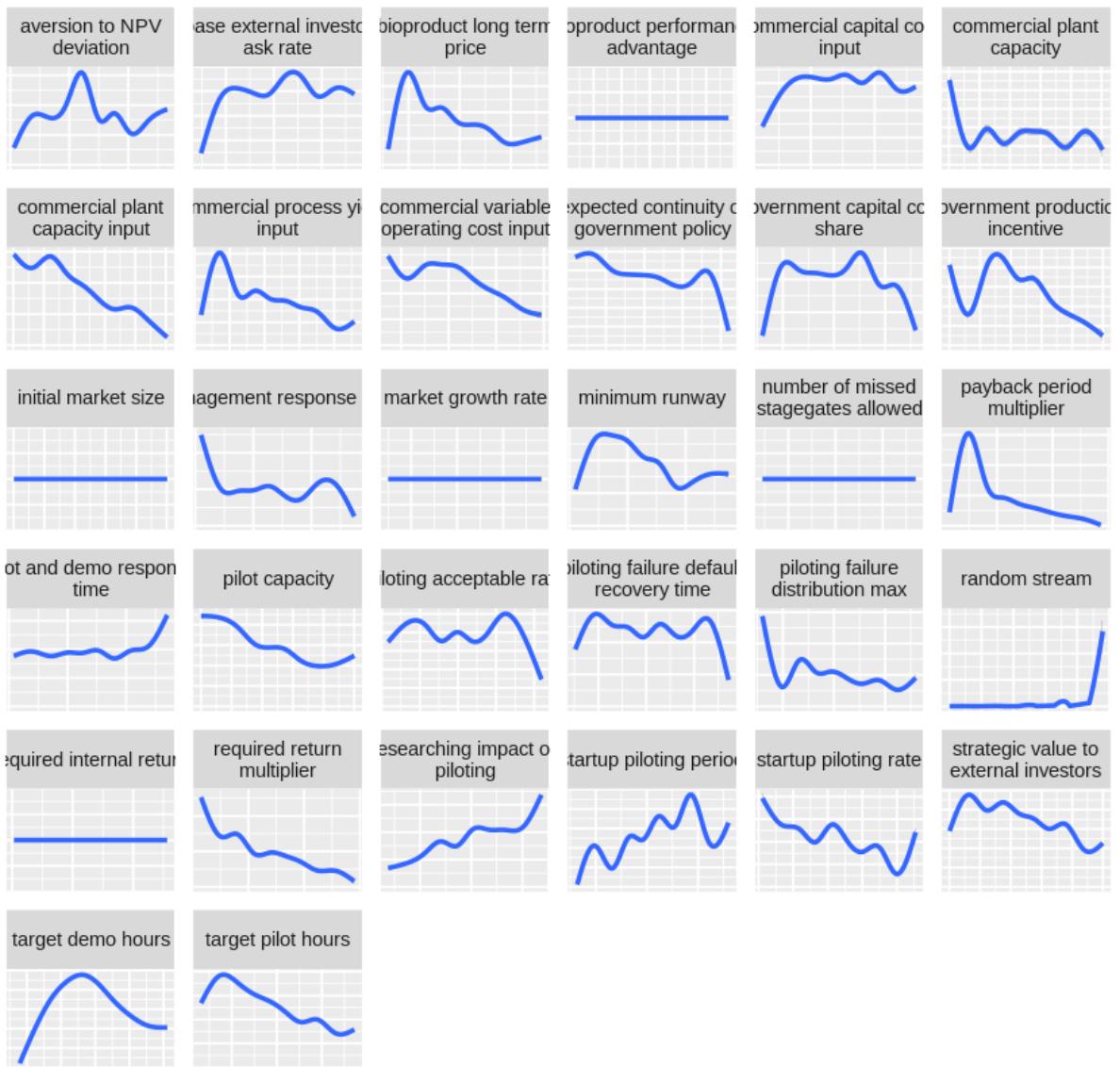
Variance-Based Sampling Density for stage in progress



Warning message:

"Removed 88 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for startup demoing completed

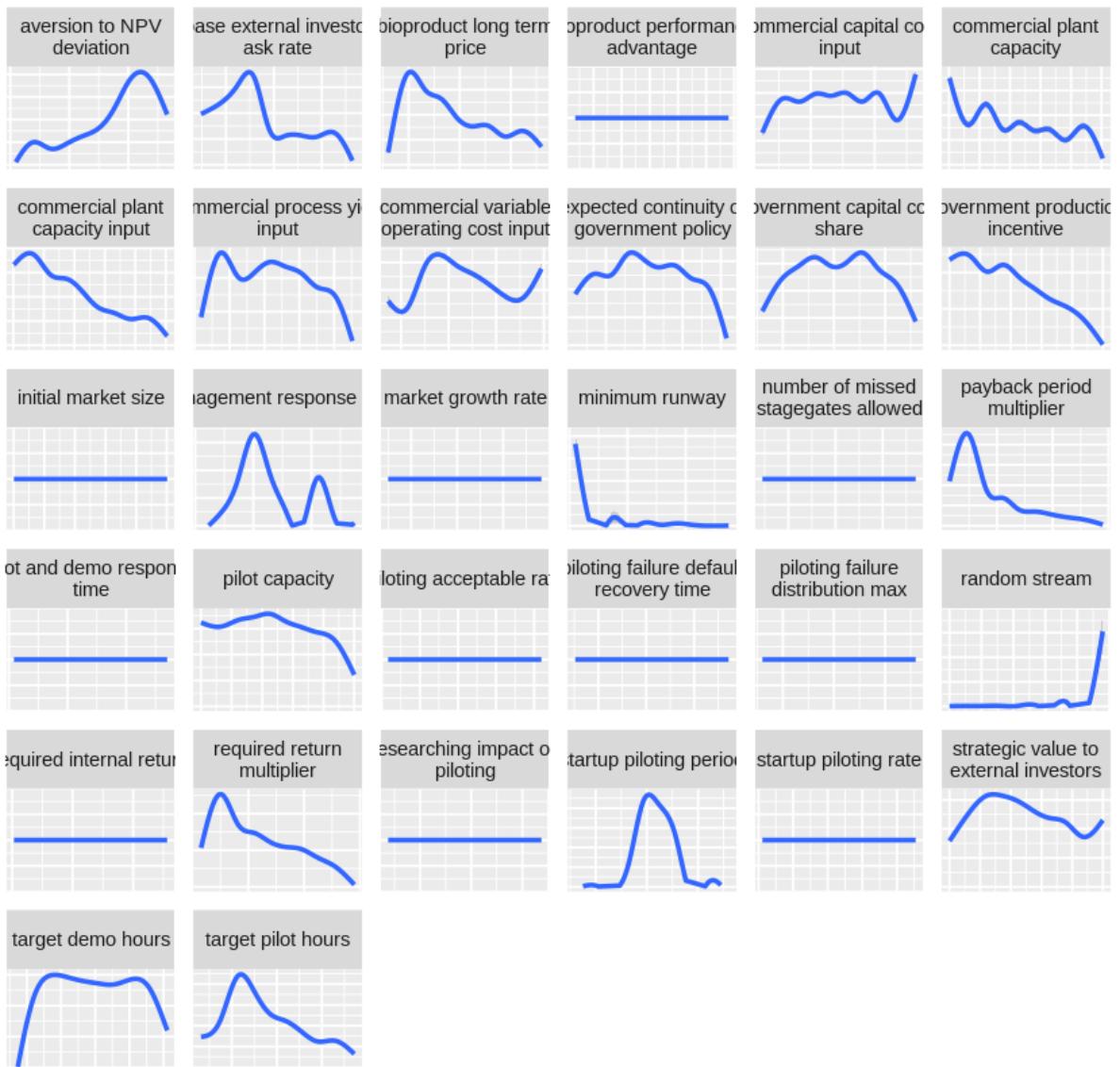


Warning message:

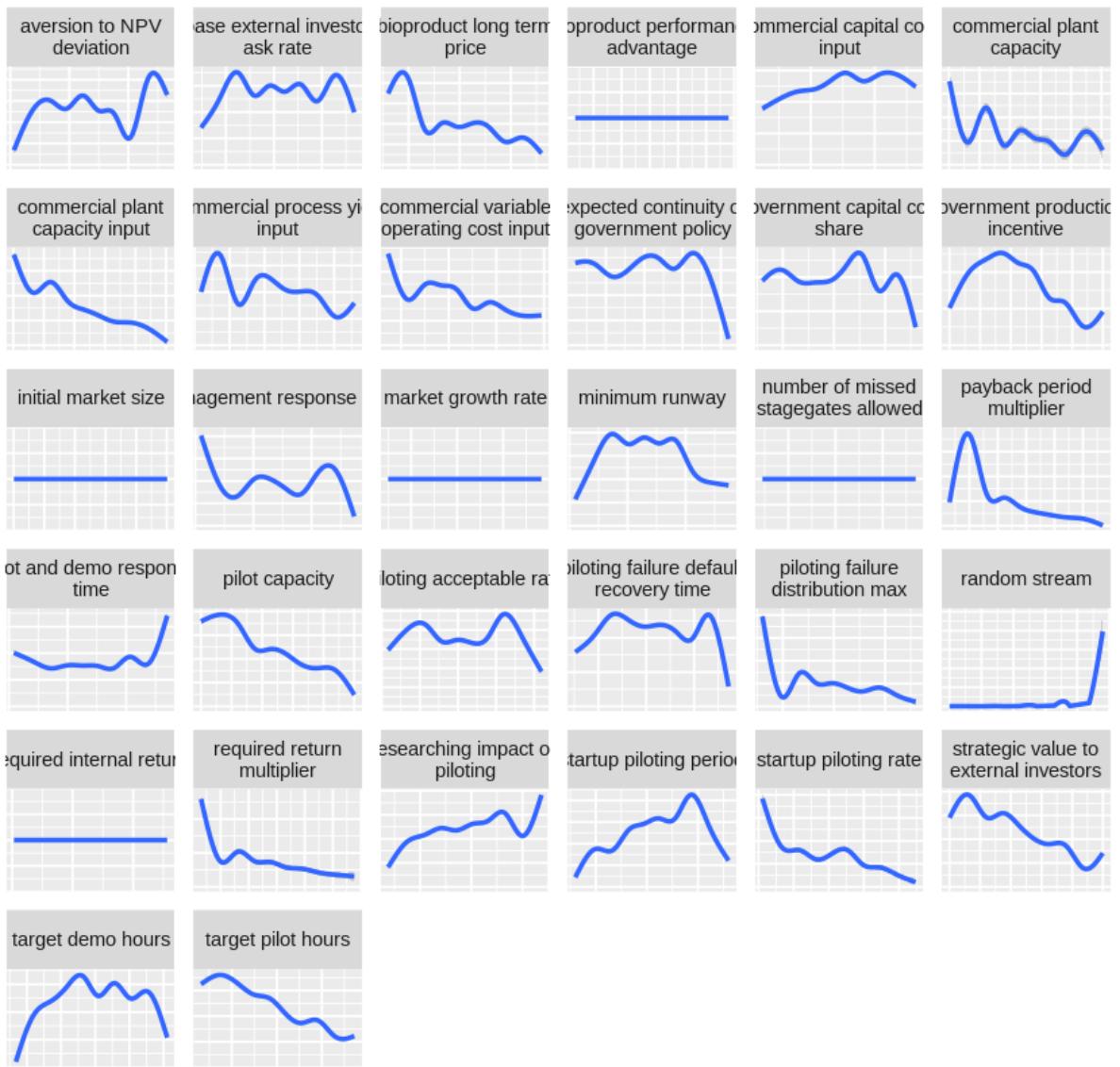
"Removed 135 rows containing non-finite values (stat_smooth)." "Warning message:

"Removed 25 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density for startup piloting complete



Variance-Based Sampling Density for technology readiness level



```
In [16]: z.metric <- z.density[
  , .(Density = sum(Index) / (sum(Weight) + 1e-10)), by = .(Input, Output, x)
]
z.metric <- merge(
  z.metric
, z.metric[, .(Scale = sum(Density)), by = .(Input, Output)])
)[
  Scale > 0
][
  , .(Density = Density / Scale), by = .(Input, Output, x)
][
  , .(Density = mean(Density)), by = .(Input, x)
][
  order(Input, x)
][
  , .(x, Density, Cumulative = cumsum(Density)), by = Input
]
z.metric %>% summary
```

Input	x	Density	Cumulative
Length:104509 000	Min. :0.000e+00	Min. :0.0000000	Min. :0.0
Class :character 831	1st Qu.:1.000e+00	1st Qu.:0.0002181	1st Qu.:0.2
Mode :character 757	Median :9.000e+00	Median :0.0002763	Median :0.5
	Mean :3.474e+07	Mean :0.0002871	Mean :0.5
475	3rd Qu.:7.640e+03	3rd Qu.:0.0003230	3rd Qu.:0.8
252	Max. :1.321e+09	Max. :0.6936041	Max. :1.0
000			

Overall sampling density.

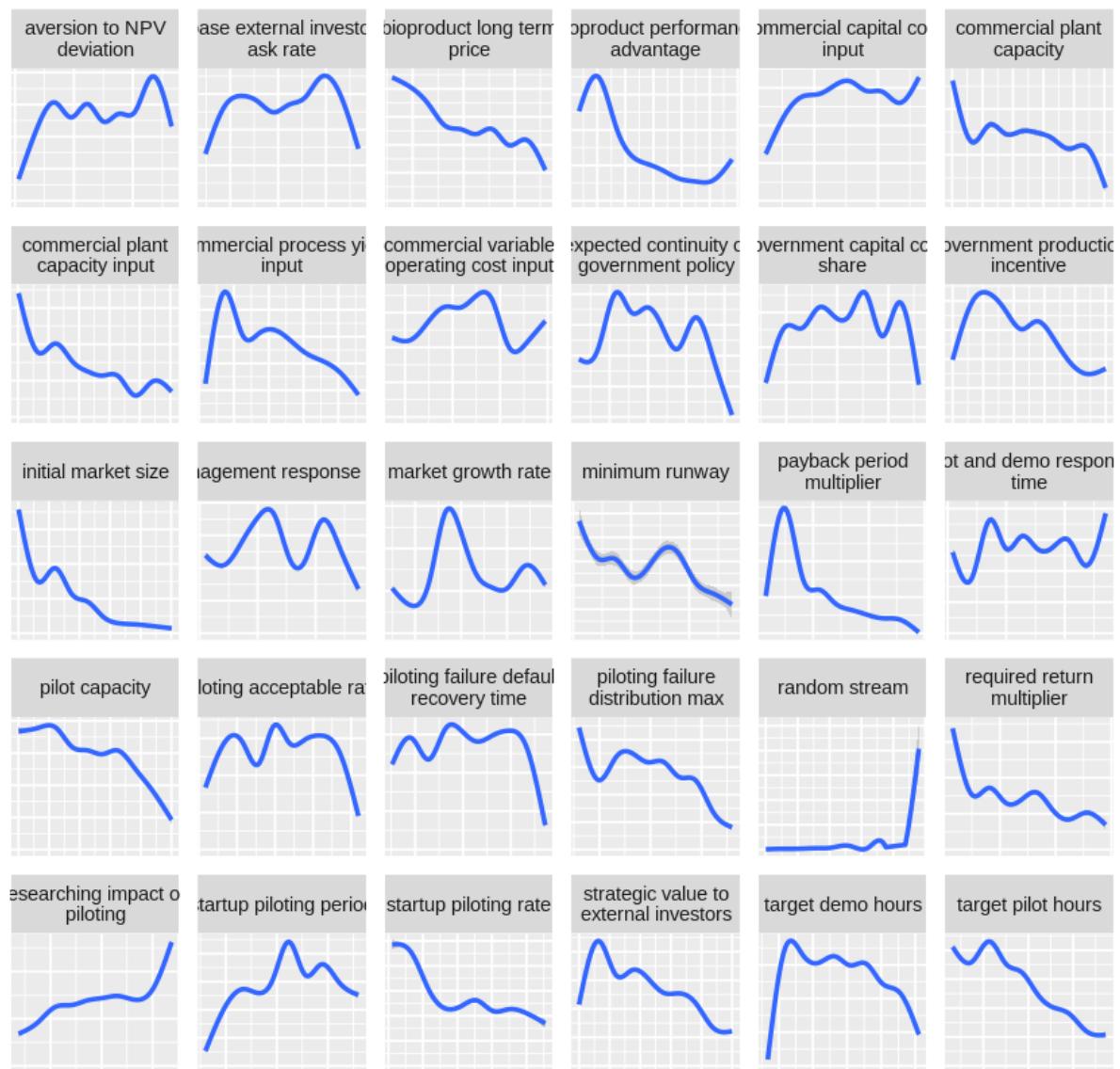
```
In [17]: ggplot(  
    z.metric  
, aes(x = x, y = Density)  
) +  
geom_smooth(method = "gam", formula = y ~ s(x, bs = "cs")) +  
scale_y_continuous(limits = c(0, NA)) +  
facet_wrap(. ~ Input, scales = "free", labeller = label_wrap_gen()) +  
gtitle("Variance-Based Sampling Density") +  
theme(  
    axis.title.x =element_blank()  
, axis.text.x =element_blank()  
, axis.ticks.x =element_blank()  
, axis.title.y =element_blank()  
, axis.text.y =element_blank()  
, axis.ticks.y =element_blank()  
)
```

Warning message:

"Removed 5 rows containing non-finite values (stat_smooth)." Warning message:

"Removed 10 rows containing missing values (geom_smooth)."

Variance-Based Sampling Density



Cumulative total sensitivity.

```
In [18]: for (icol in 5:ncol(yy)) {

  y0 <- yy[, icol, with = FALSE][[1]]
  ya <- y0[1:n]
  yb <- y0[1:n + n]
  ybia <- matrix(y0[-(1:(2*n))], nrow = n, byrow = FALSE)
  xyab <- NULL
  for (i in 1:32) {
    temp <- data.table(
      Input = colnames(z.inputs)[1+i],
      xA = as.matrix(xa[, i + 1, with=FALSE]),
      xB = as.matrix(xb[, i + 1, with=FALSE]),
      yA = ya,
      yB = yb,
      yBiA = ybia[, i]
    )
    colnames(temp) <- c("Input", "xA", "xB", "yA", "yB", "yBiA")
    scale <- sqrt(((temp$yA - temp$yB) %*% (temp$yA - temp$yB))[1])
    xyab <- rbind(
      xyab, cbind(
        Sample = 0,
        temp[, .(Input, xA, xB, yA = yA / scale, yB = yB / scale, yB
iA = yBiA / scale)]
      )
    )
    for (j in 1:25) {
      temp2 <- temp[sample(1:nrow(temp), nrow(temp), replace = TRUE)]
      scale <- sqrt(((temp2$yA - temp2$yB) %*% (temp2$yA - temp2$yB))
[1])
      xyab <- rbind(
        xyab,
        cbind(
          Sample = j,
          temp2[, .(Input, xA, xB, yA = yA / scale, yB = yB / scal
e, yBiA = yBiA / scale)])
      )
    }
  }
  xyab.sensitivity <- xyab[, .(
    S = 1 - sum((yA - yBiA)^2),
    T = sum((yB - yBiA)^2)
  ), by = .(Sample, Input)]
  xyab.best <- xyab.sensitivity[T >= 0.25][order(-T)][, unique(Input)]
  if (length(xyab.best) == 0)
    next
  xyab.temp <- rbind(xyab[, .(Input, Sample, x = xA, yB, yBiA)], xyab[, .
  (Input, Sample, x = xB, yB, yBiA)][
    Input %in% xyab.best,
    .(Sample, Input=factor(Input, levels = xyab.best), x, yB = yB /
sqrt(2), yBiA = yBiA / sqrt(2))]
  ][
    order(Input, Sample, x)
  ][,
    .(x, T = cumsum((yB - yBiA)^2)), by = .(Input, Sample)
  ]
}
```

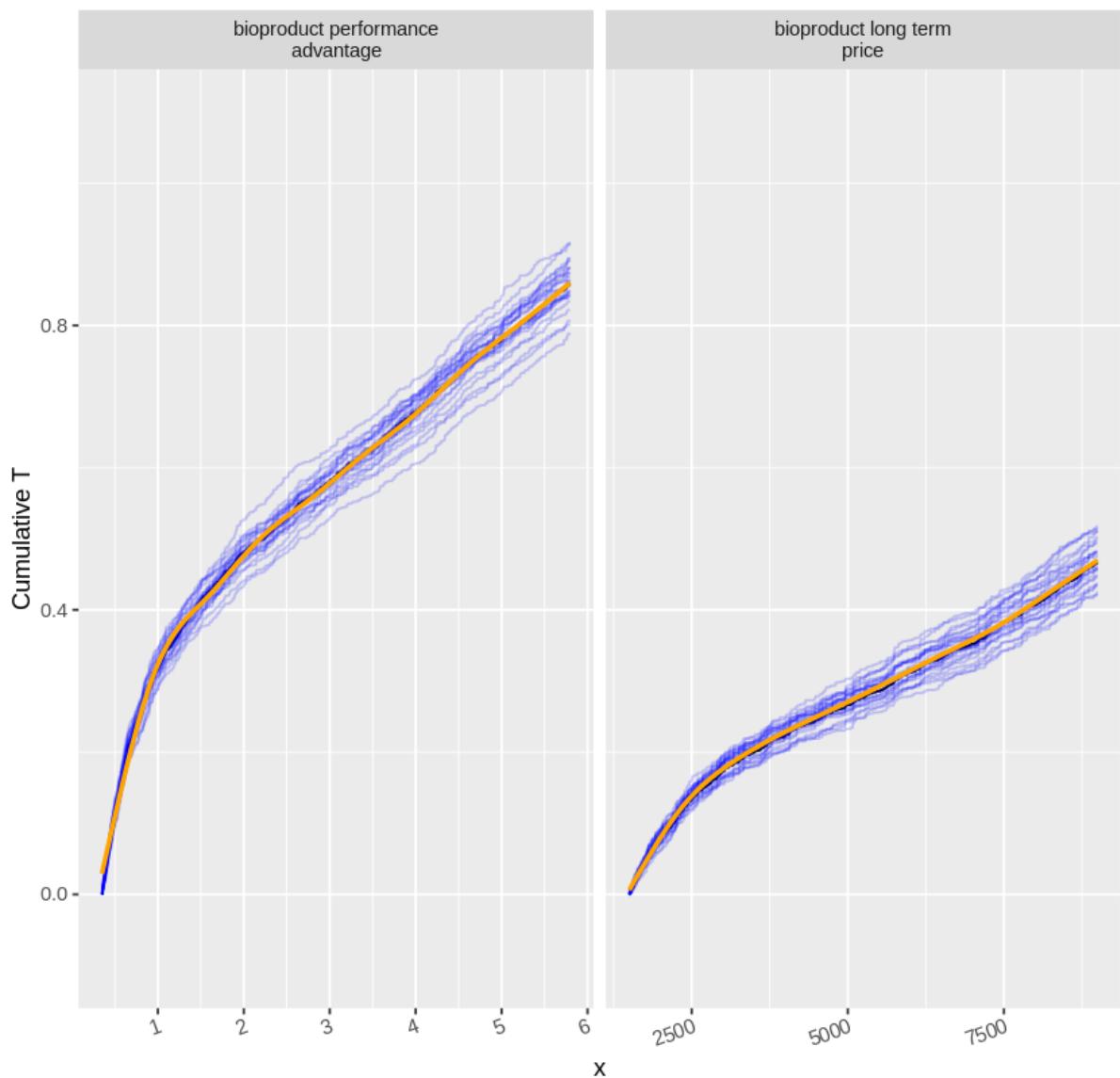
```

        ]
g <- ggplot(xyab.temp, aes(x = x, y = T)) +
  geom_line(data = xyab.temp[Sample == 0], color = "black", aes(group =
  Sample)) +
  geom_line(alpha = 0.2, color = "blue", aes(group = Sample)) +
  geom_smooth(color = "orange", method = "gam", formula = y ~ s(x, bs
= "cs")) +
  facet_wrap(Input ~ . , scales = "free_x", labeller = label_wrap_gen
()) +
  theme(axis.text.x = element_text(angle = 20, hjust=1)) +
  ylab("Cumulative T") +
  coord_cartesian(ylim = c(-0.1, 1.1)) +
  ggtitle(paste("Cumulative Total Sensitivity for", colnames(yy)[icol]
))
print(g)

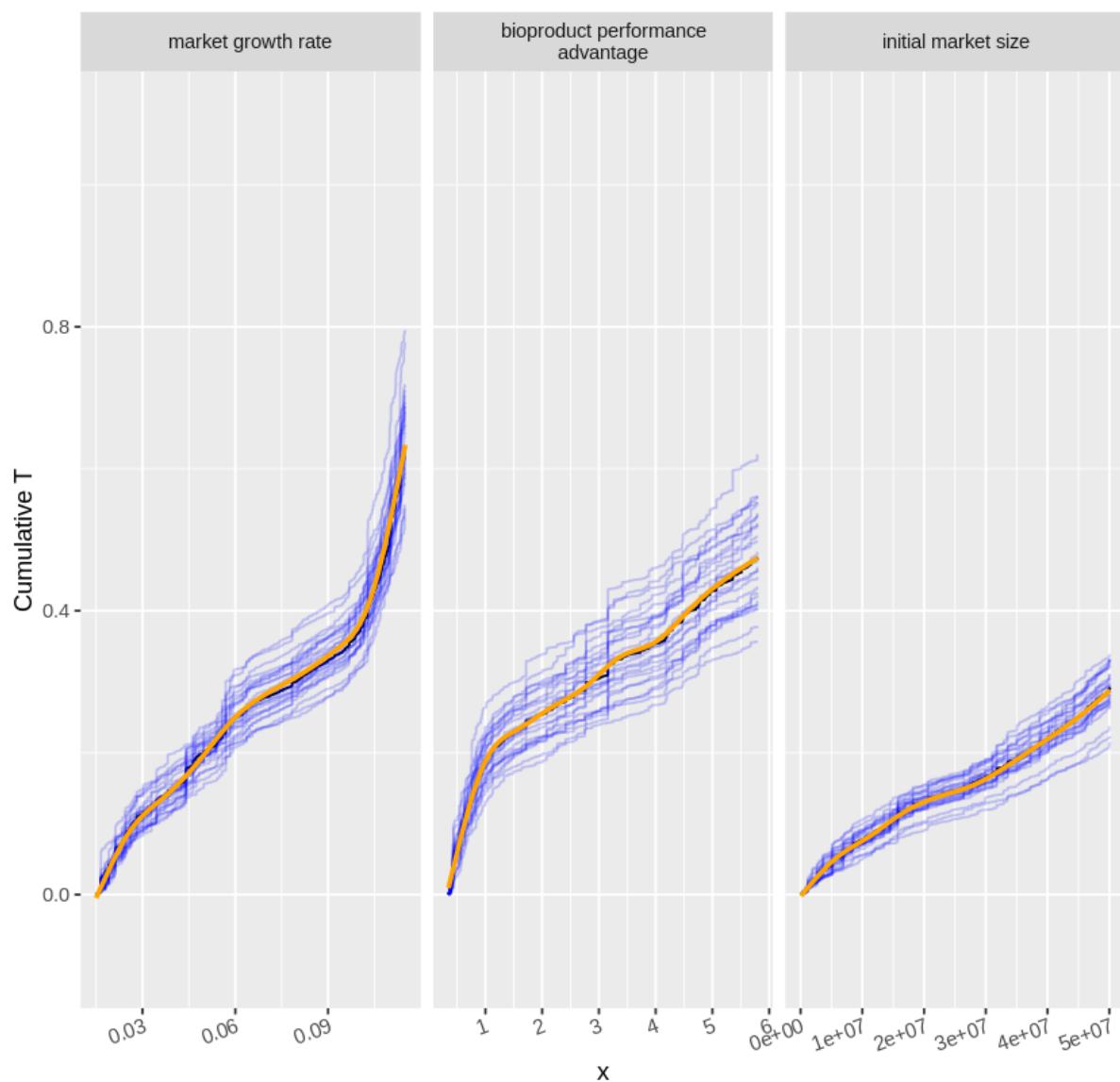
}

```

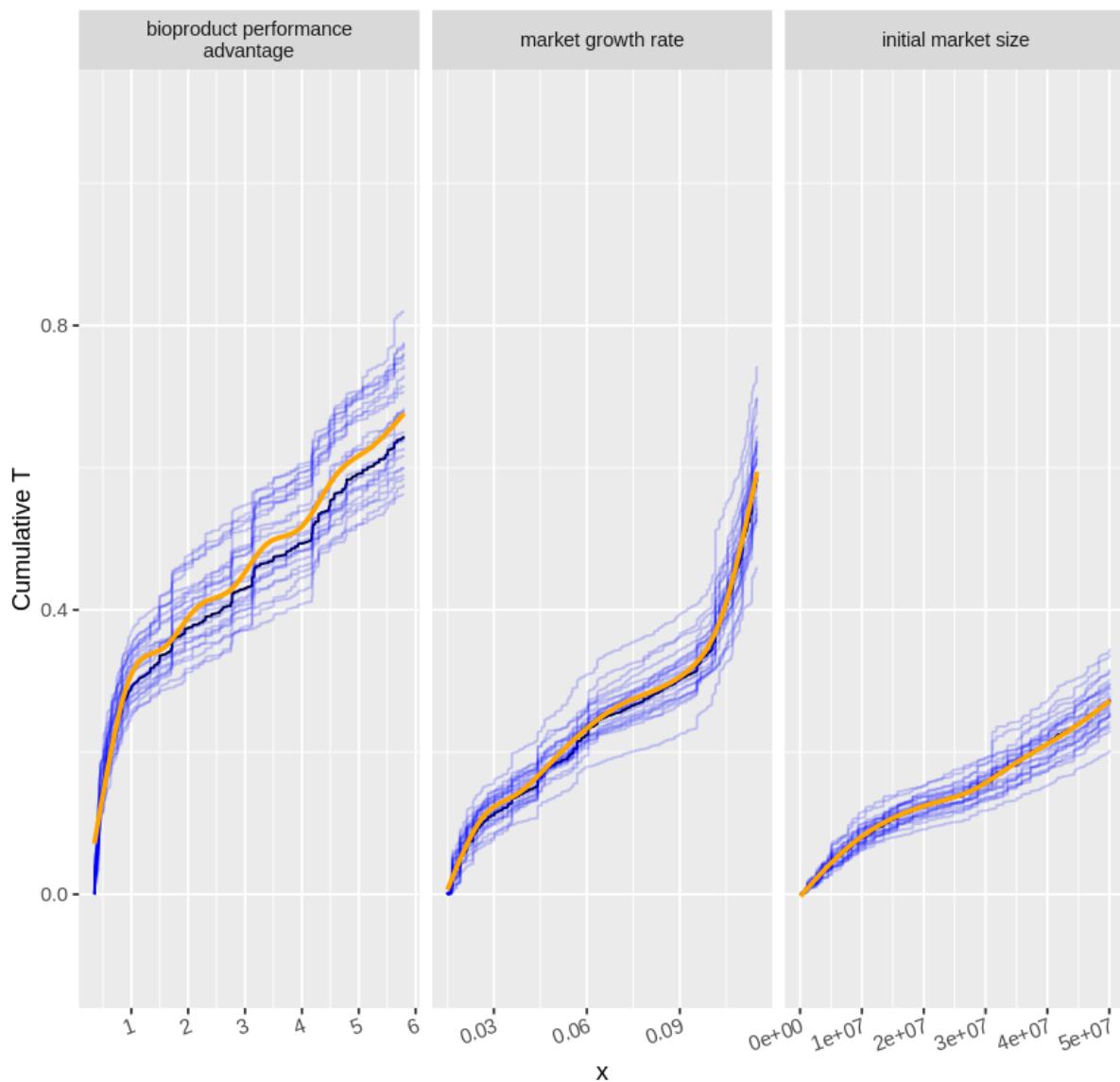
Cumulative Total Sensitivity for bioproduct market share mass



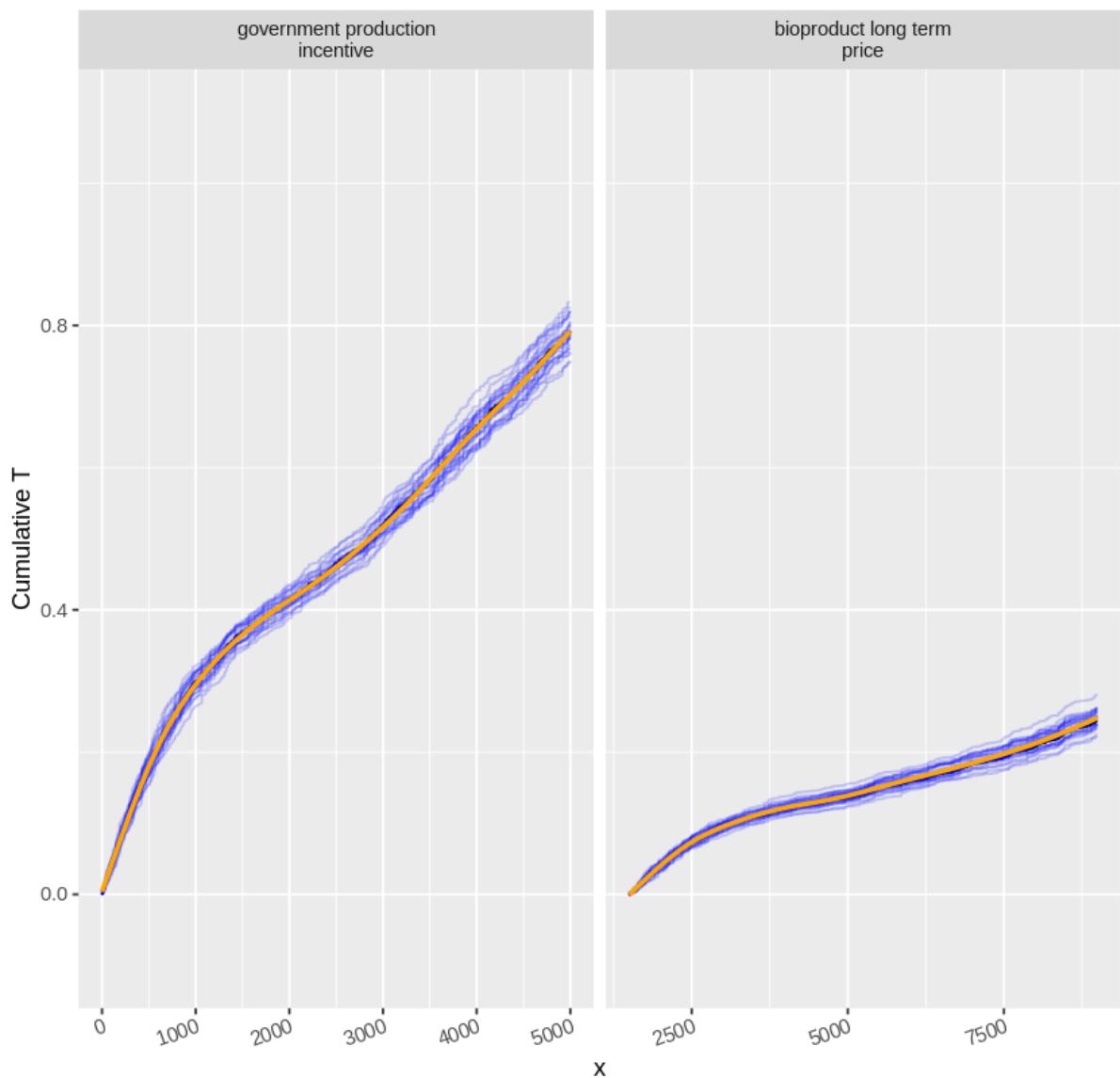
Cumulative Total Sensitivity for current market size economic



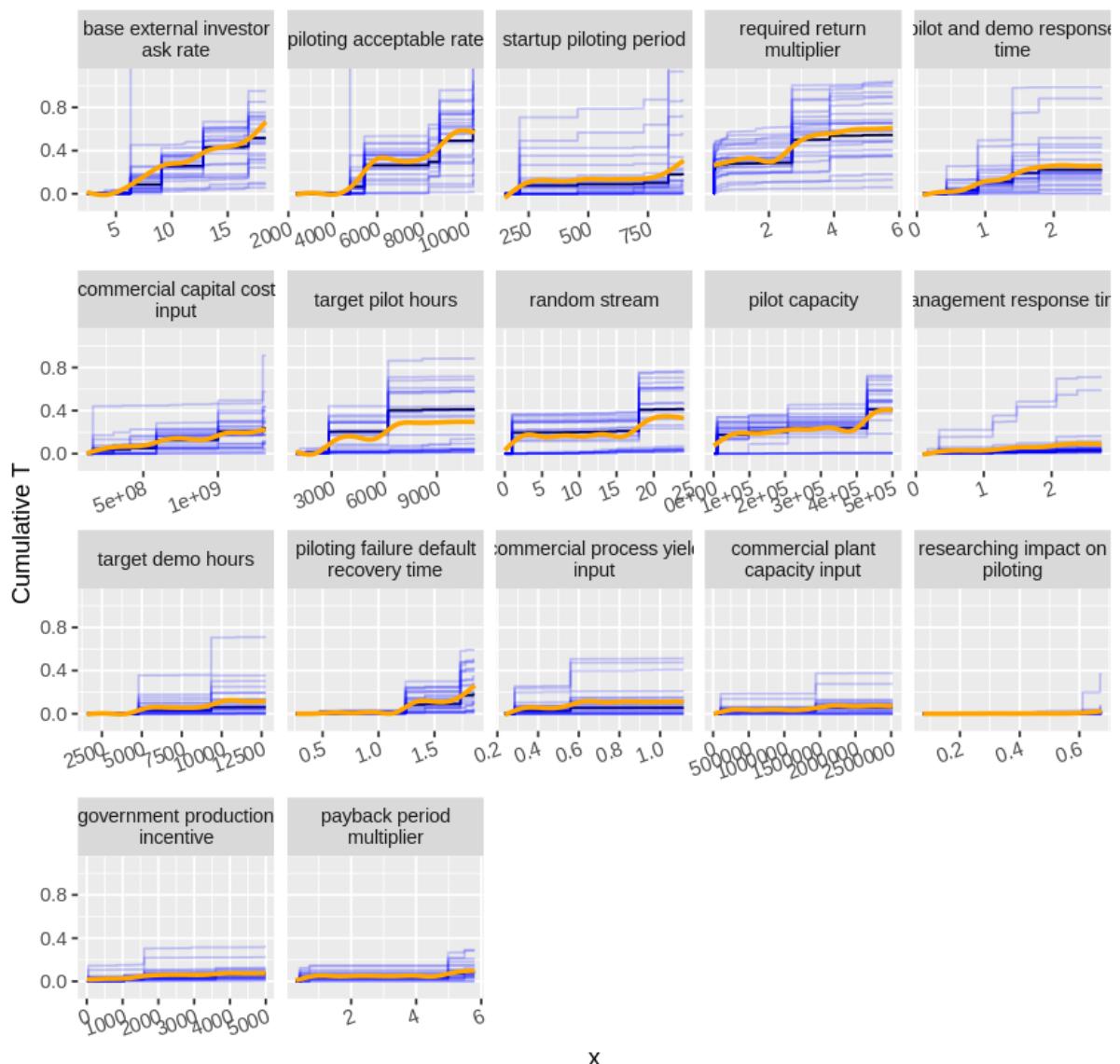
Cumulative Total Sensitivity for current market size mass



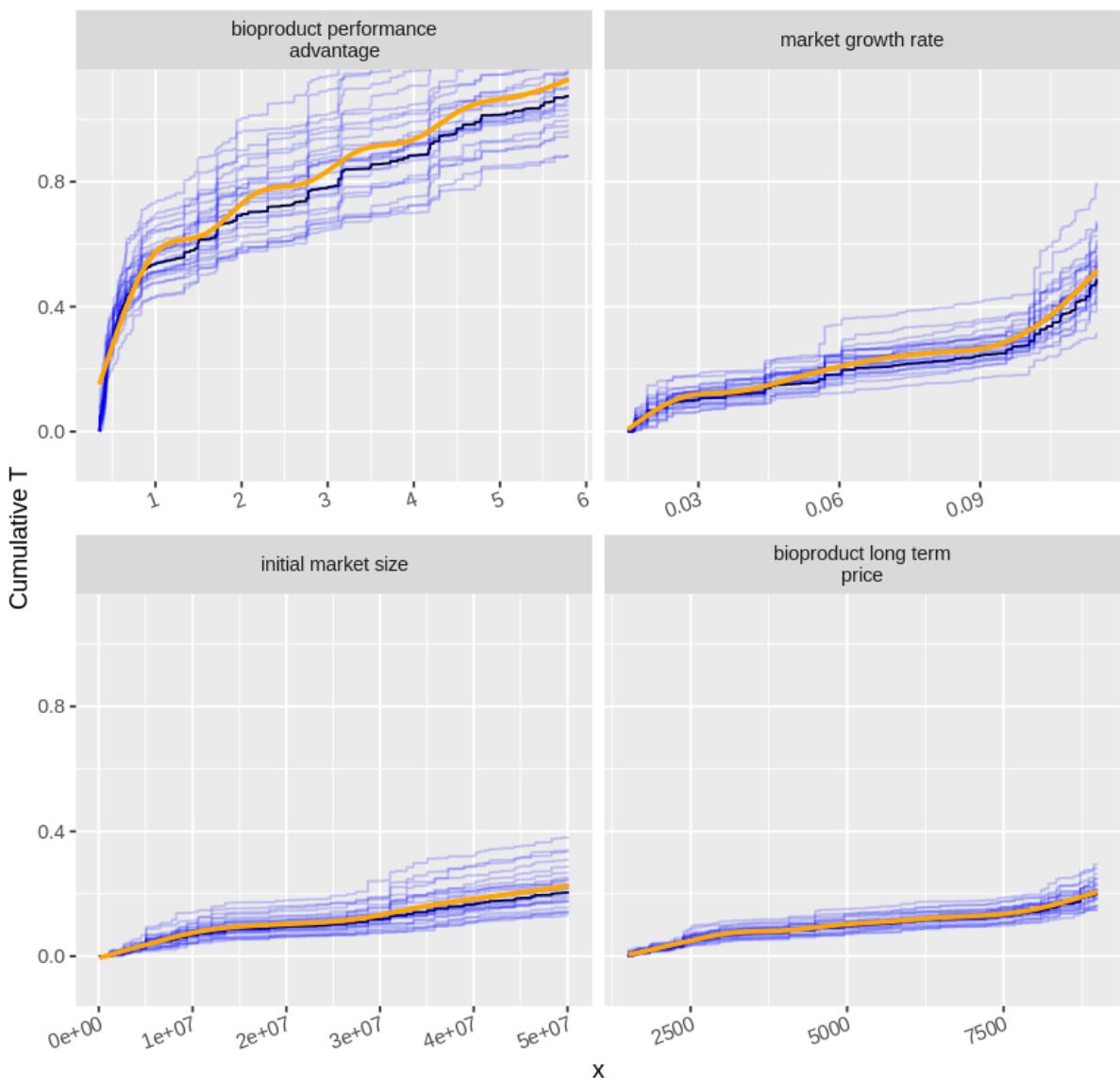
Cumulative Total Sensitivity for long term market share



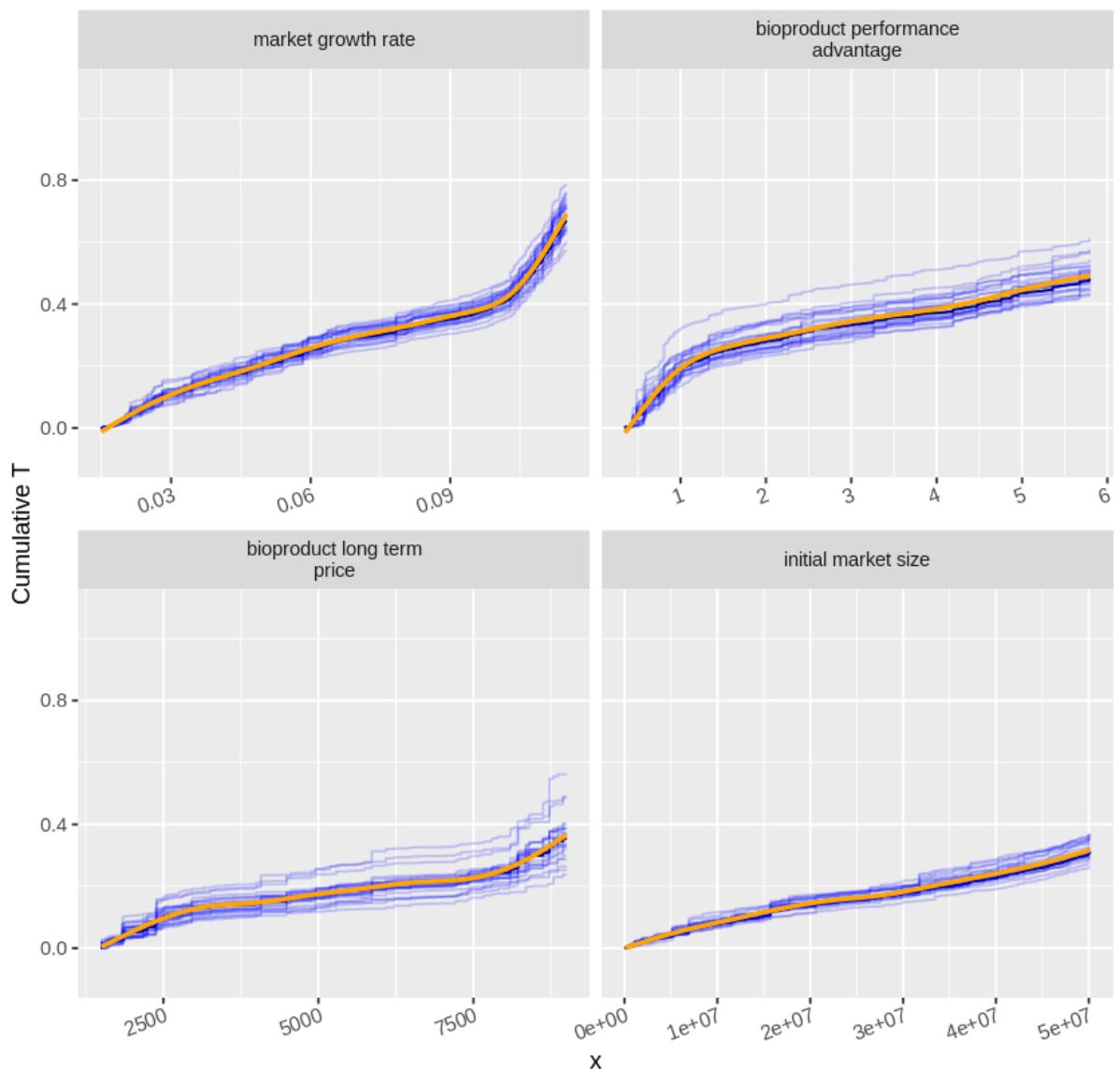
Cumulative Total Sensitivity for long term market value



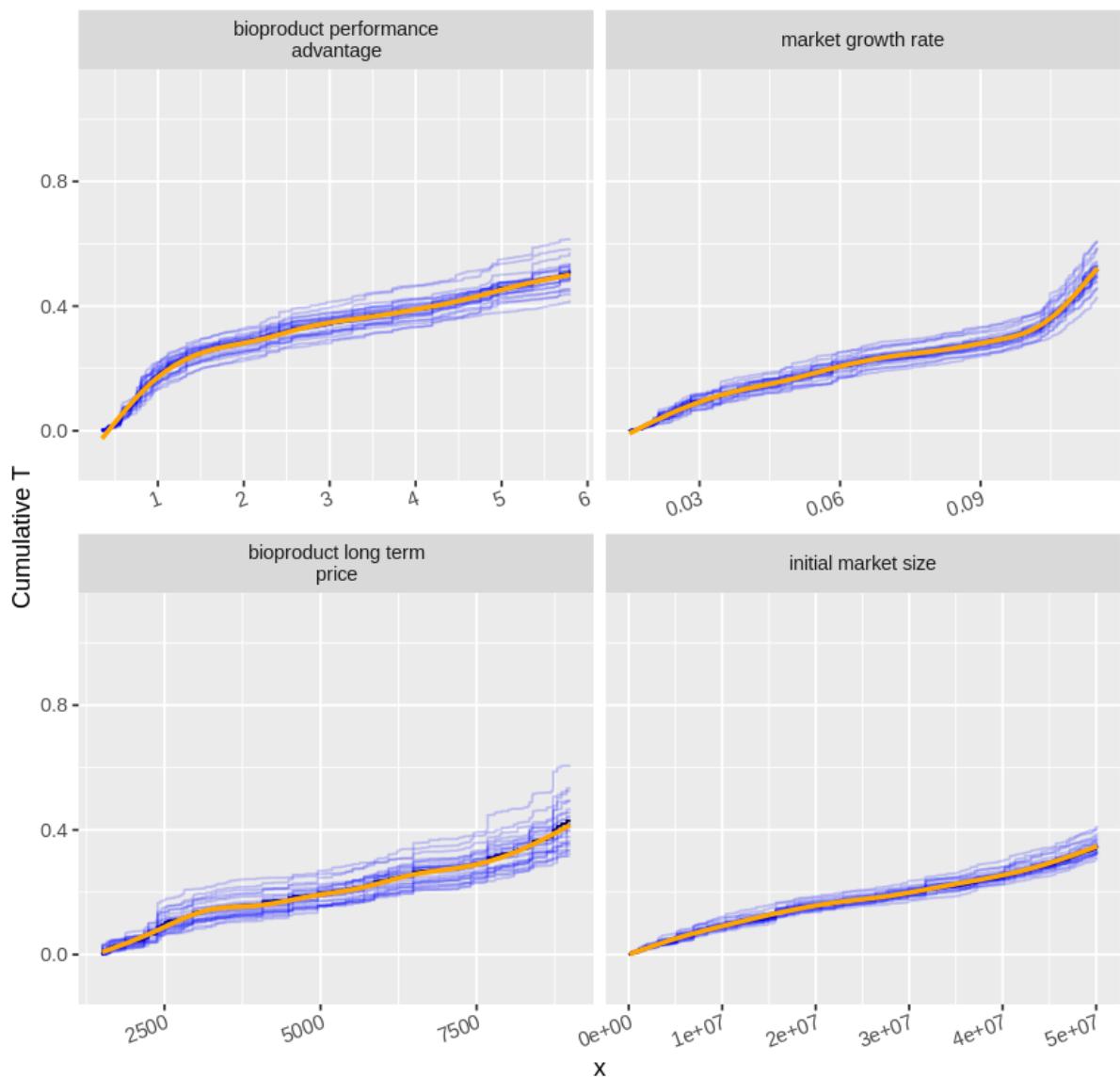
Cumulative Total Sensitivity for Adopters



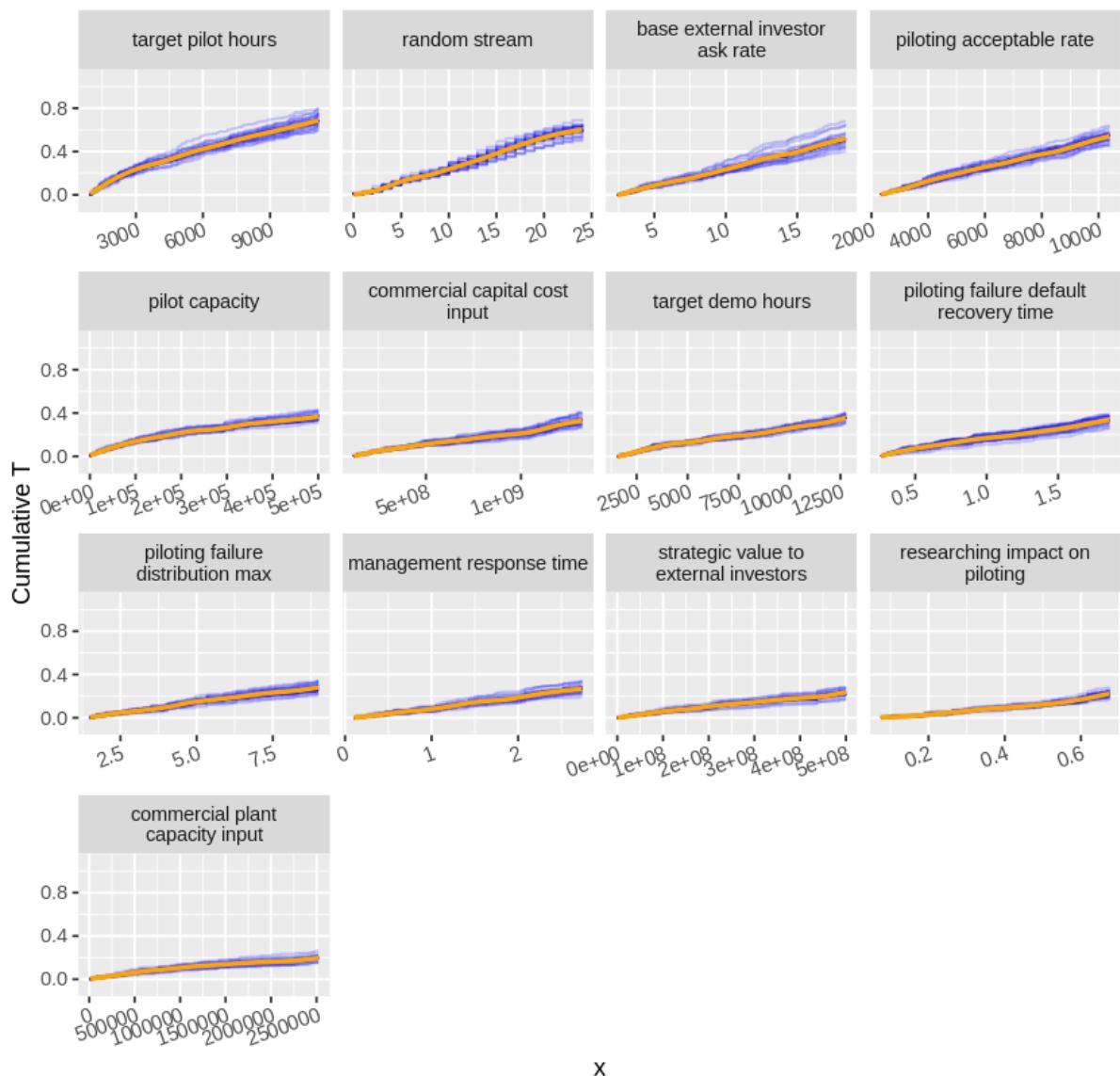
Cumulative Total Sensitivity for NonAdopters



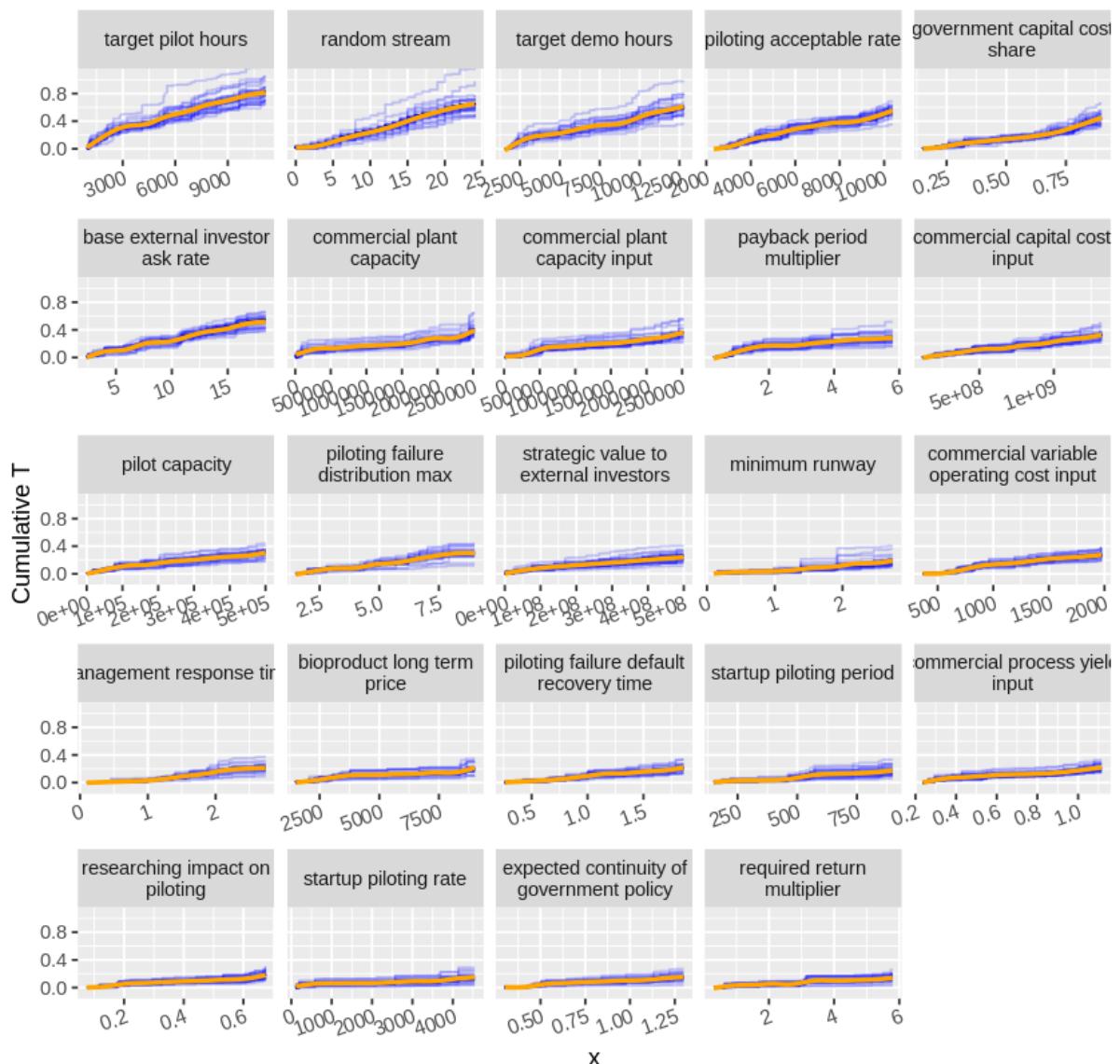
Cumulative Total Sensitivity for Potential Adopters



Cumulative Total Sensitivity for Cumulative Demoing Production



Cumulative Total Sensitivity for Cumulative Production

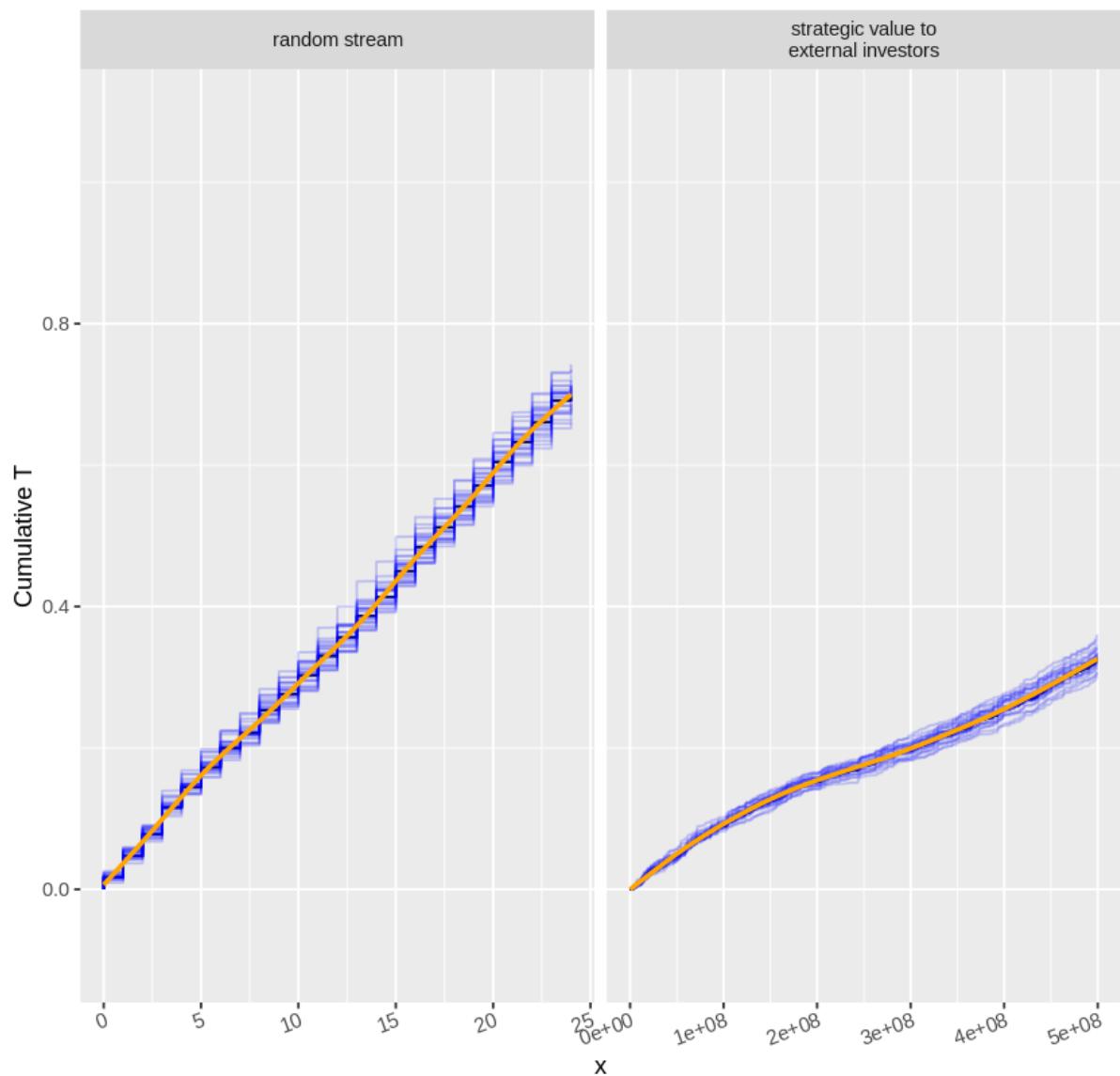


Warning message:

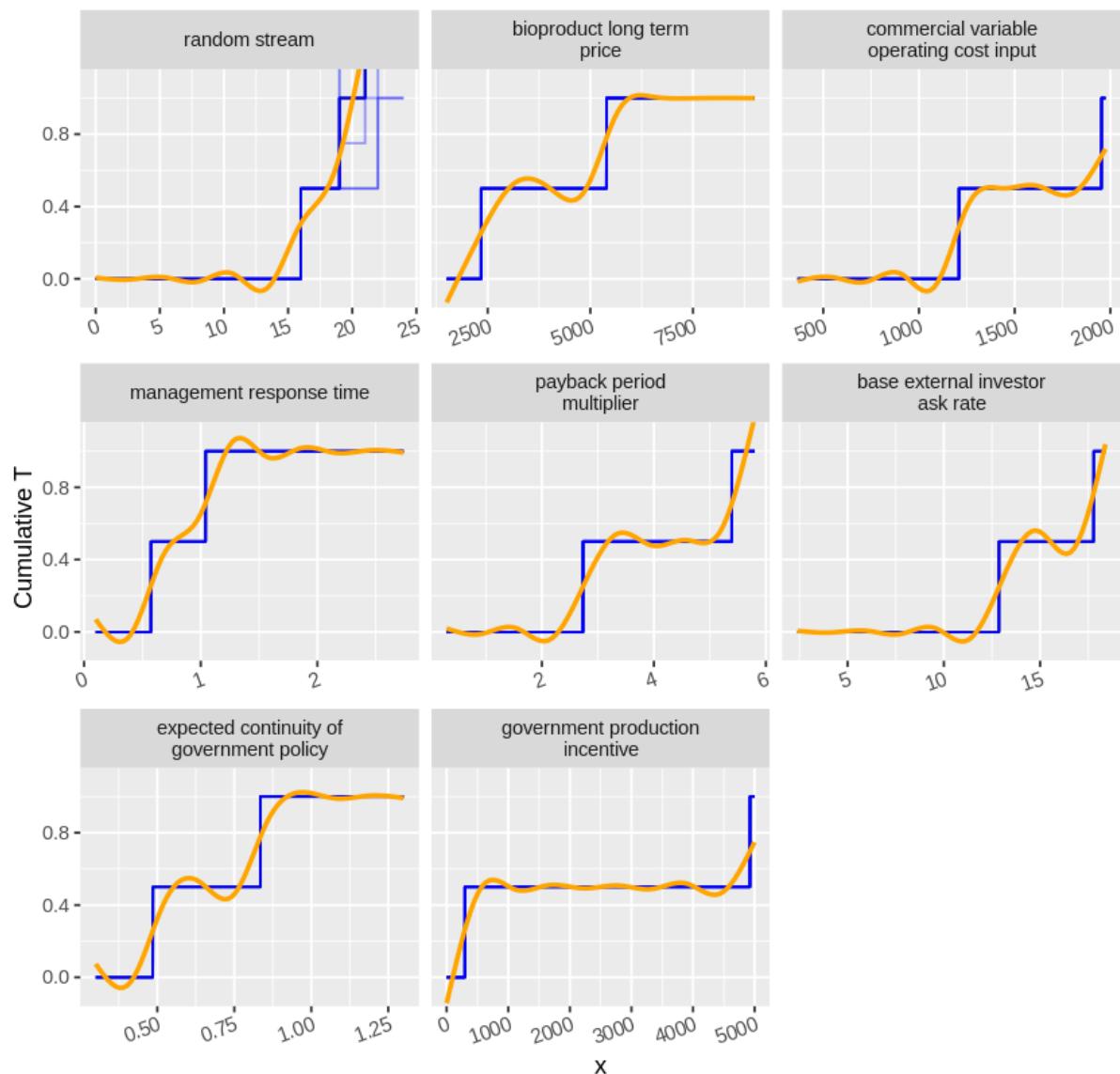
"Removed 370000 rows containing non-finite values (stat_smooth)." Warning message:

"Removed 120000 rows containing missing values (geom_path)."

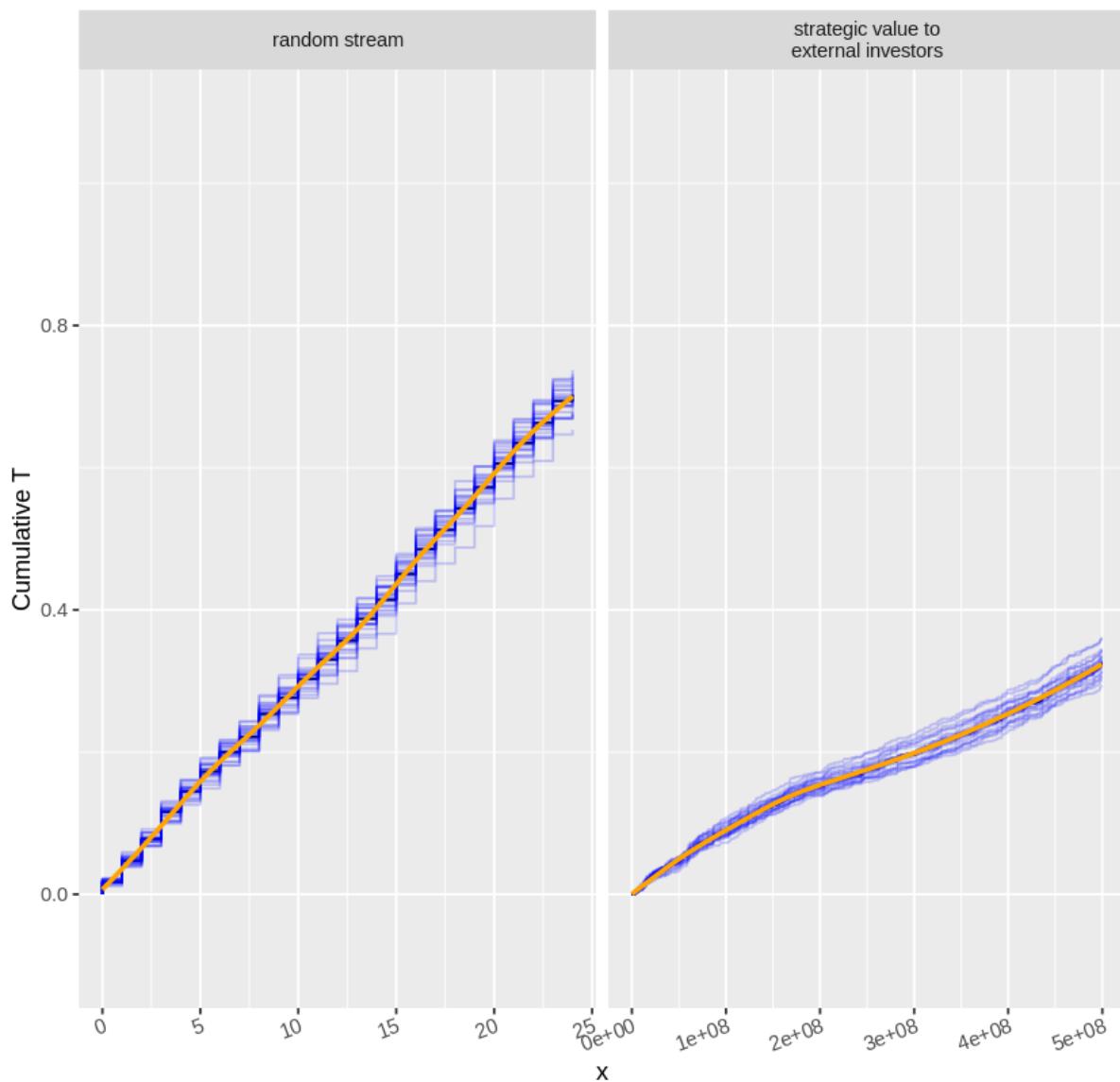
Cumulative Total Sensitivity for prepiloting



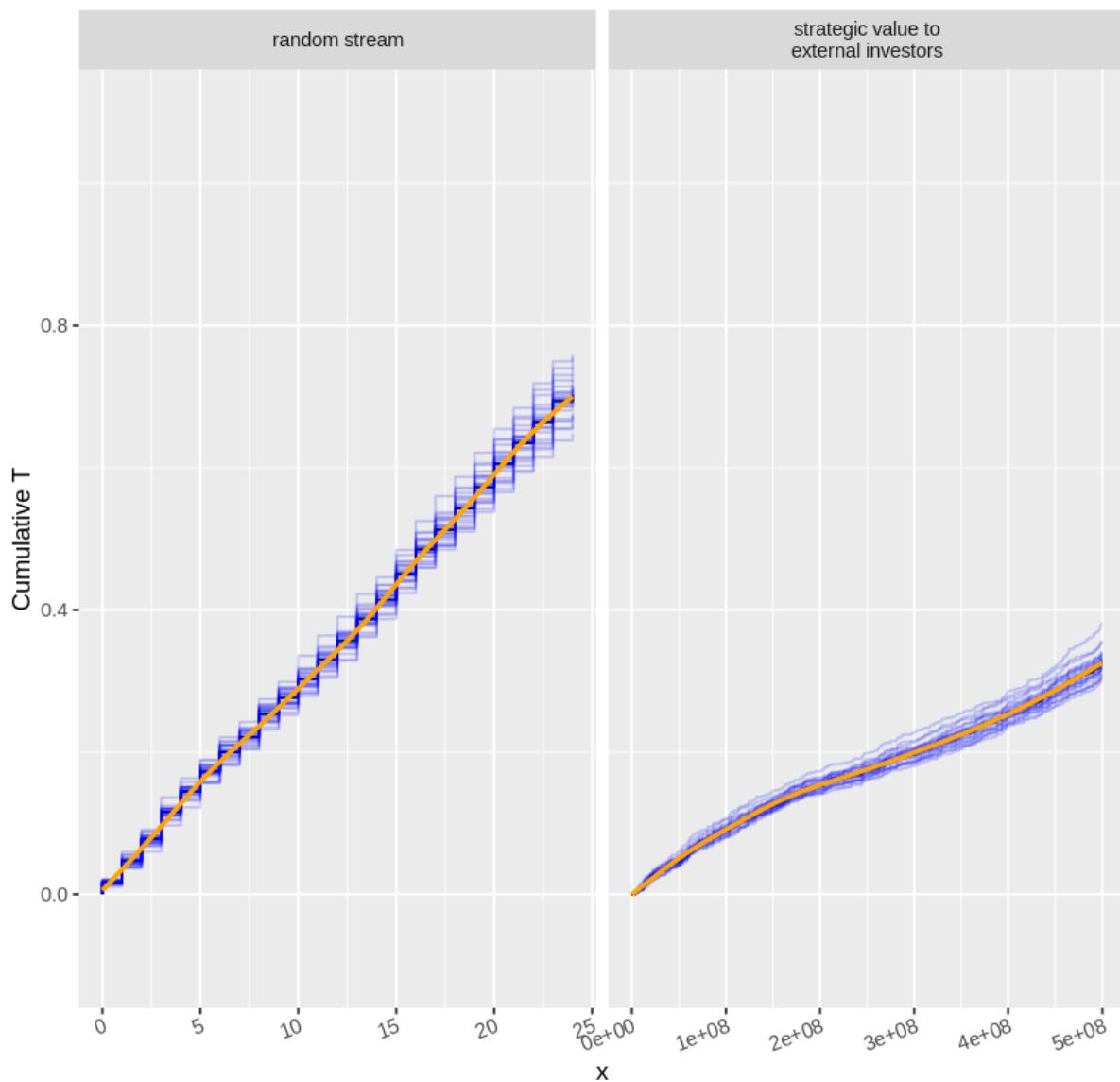
Cumulative Total Sensitivity for pilot plant construction



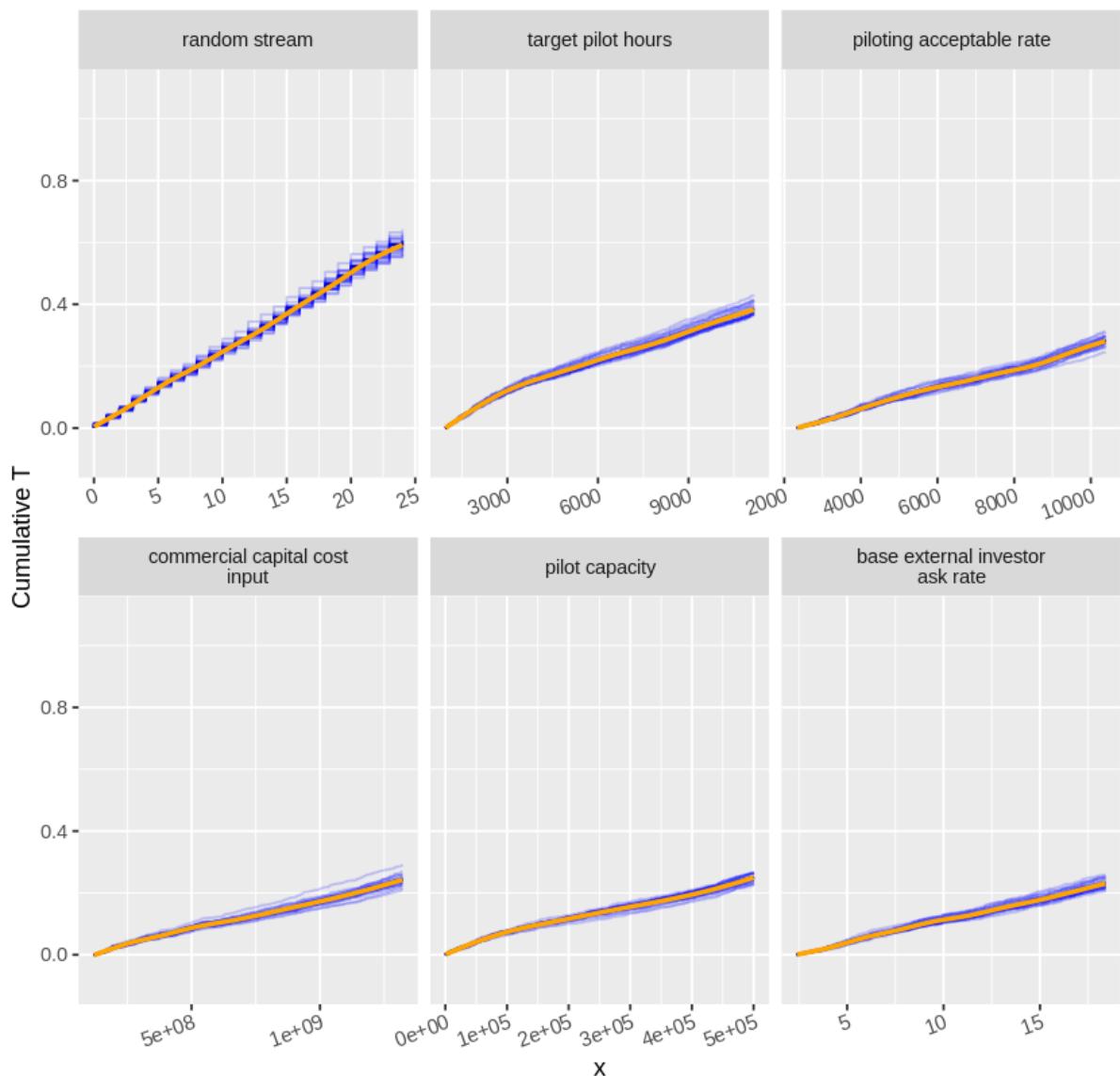
Cumulative Total Sensitivity for pilot plant is built



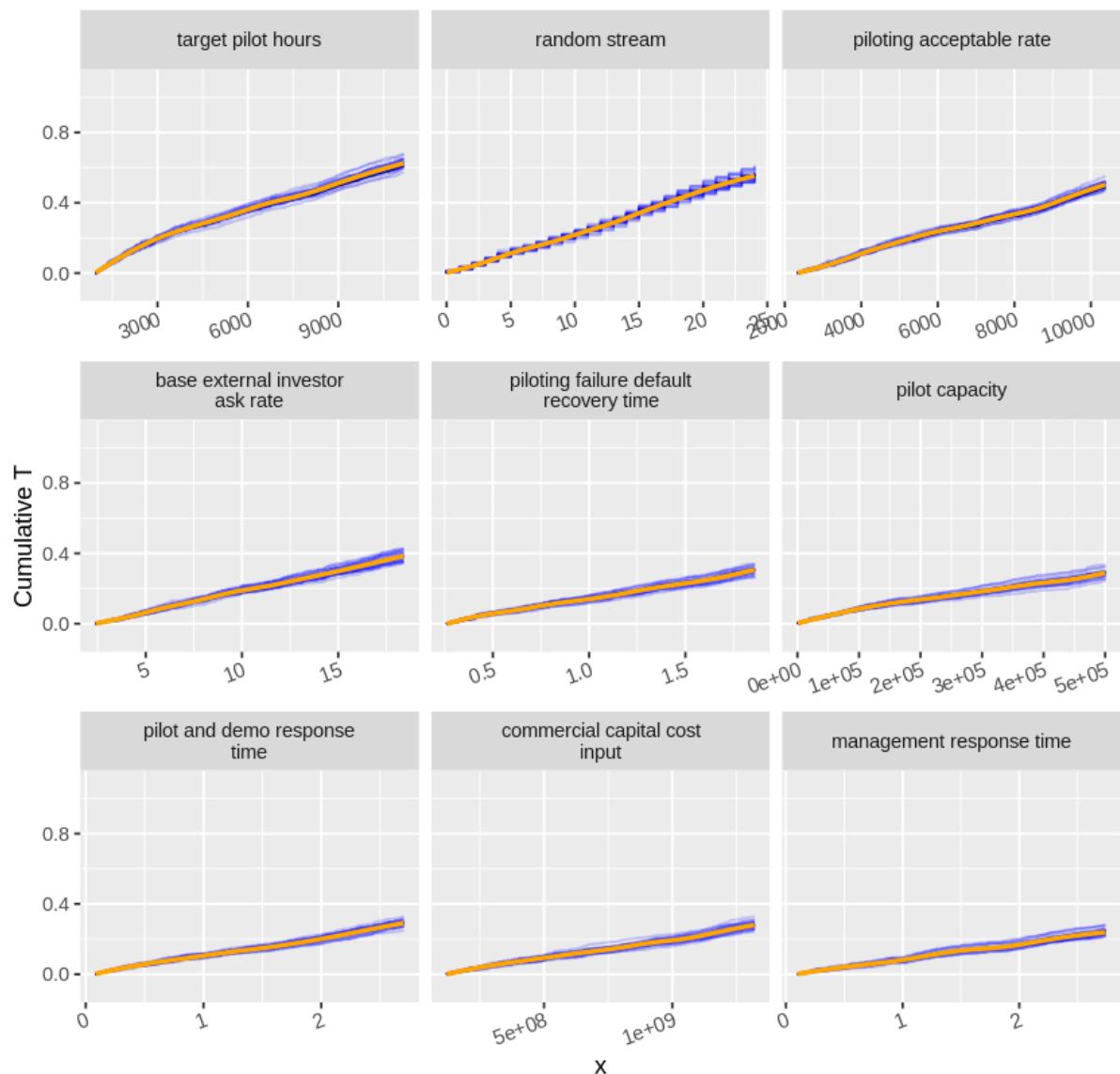
Cumulative Total Sensitivity for startup piloting complete



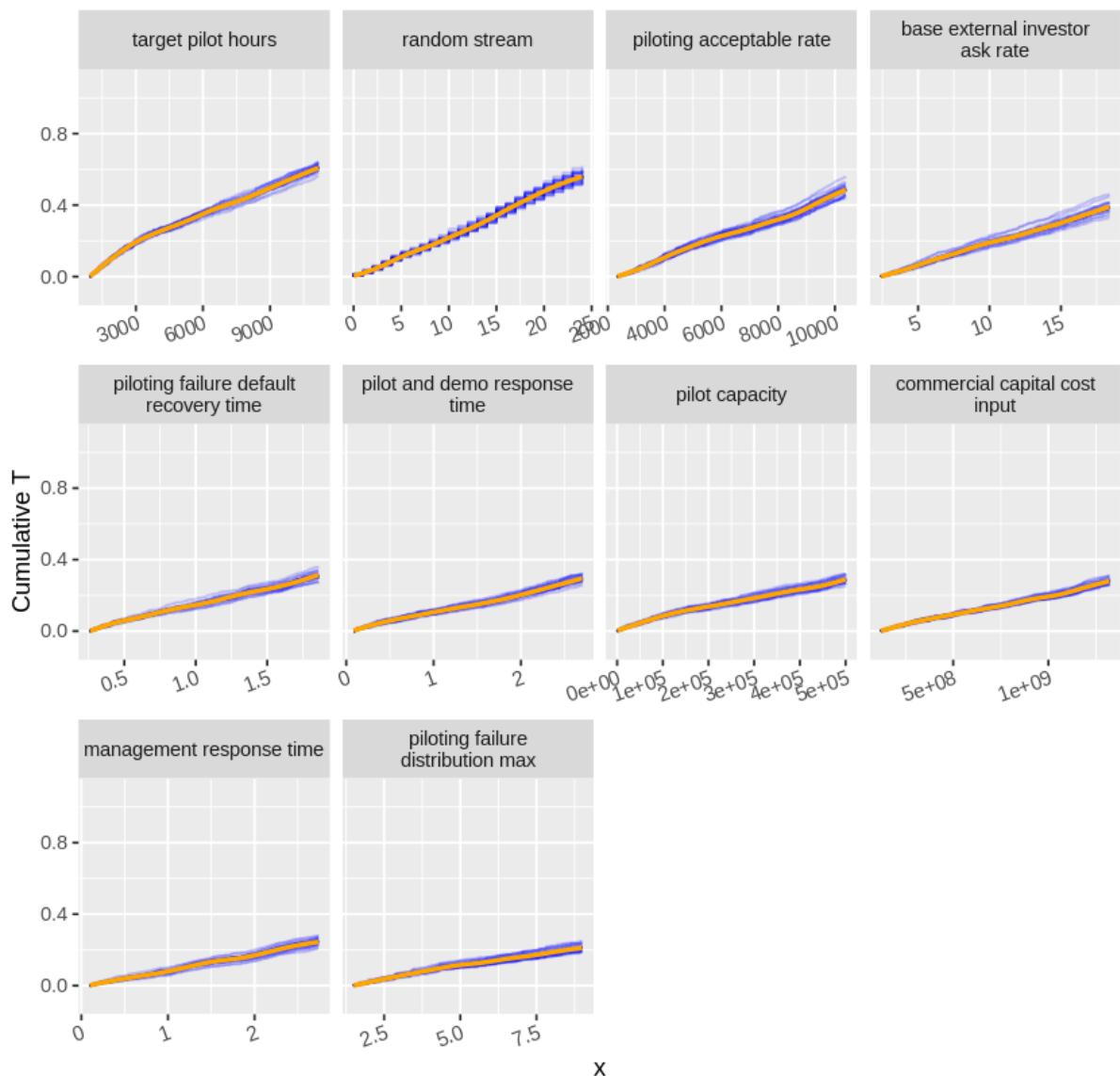
Cumulative Total Sensitivity for piloting ongoing



Cumulative Total Sensitivity for piloting progress



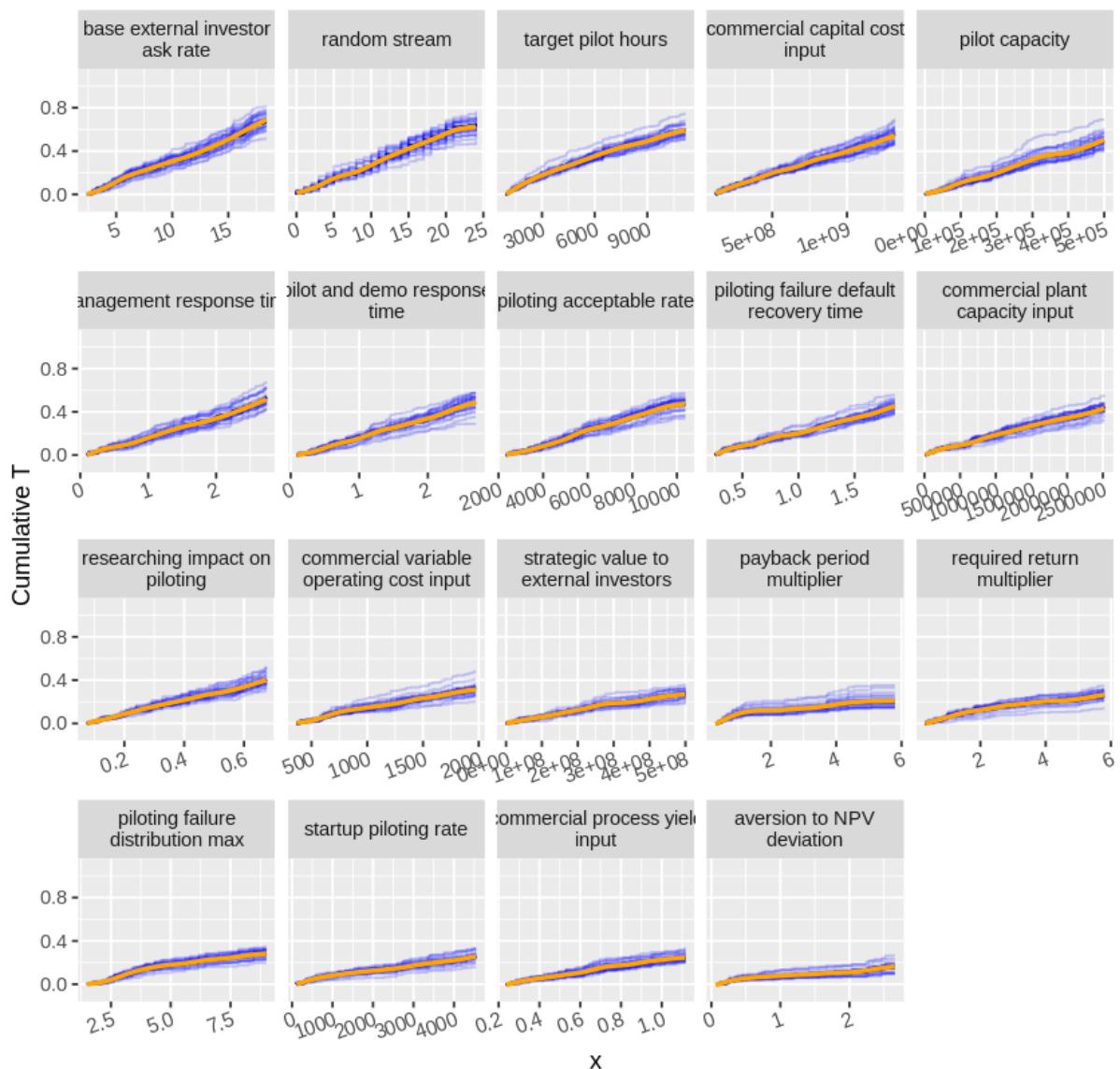
Cumulative Total Sensitivity for piloting complete



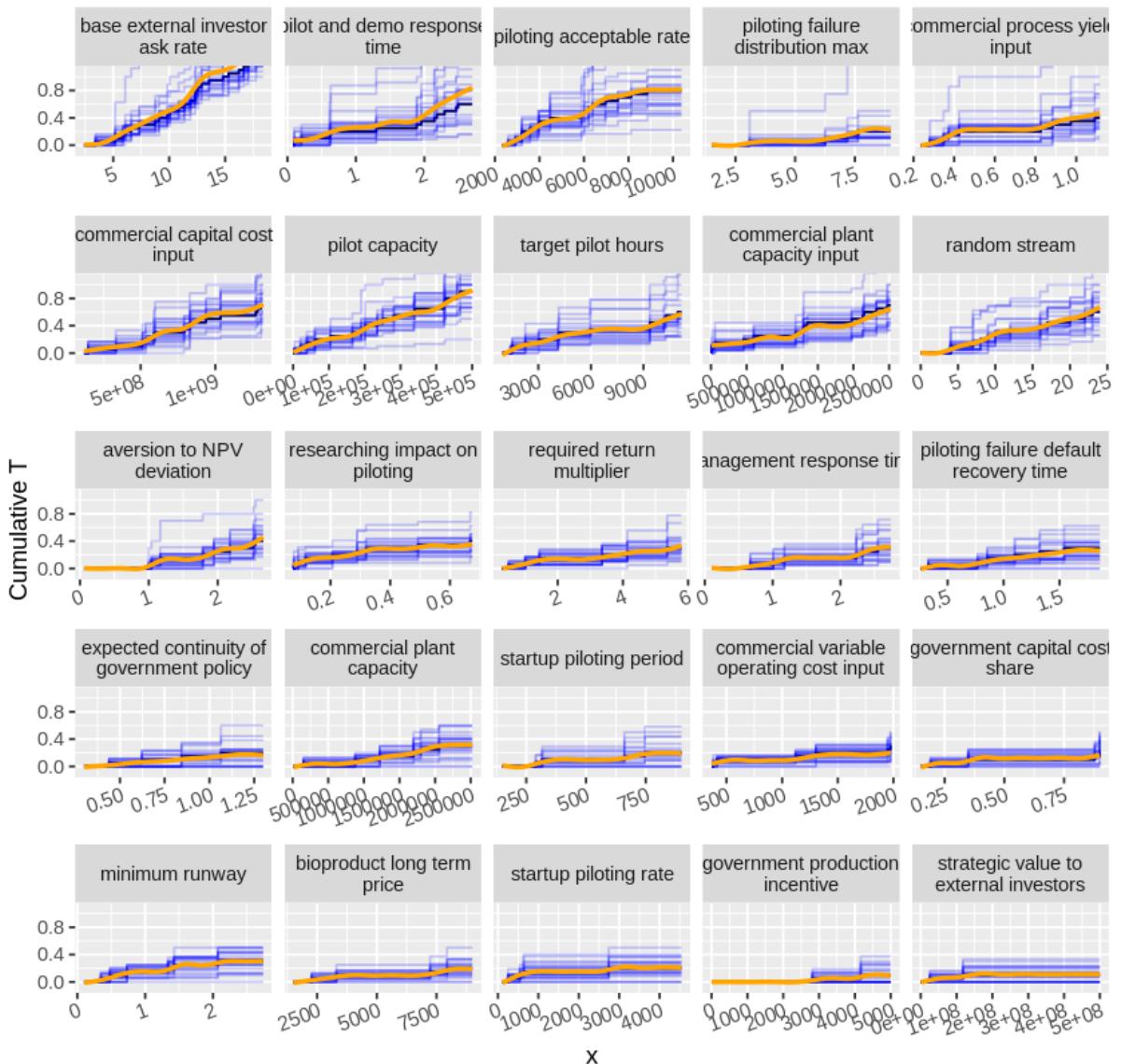
Warning message:

"Removed 5000 rows containing non-finite values (stat_smooth)."

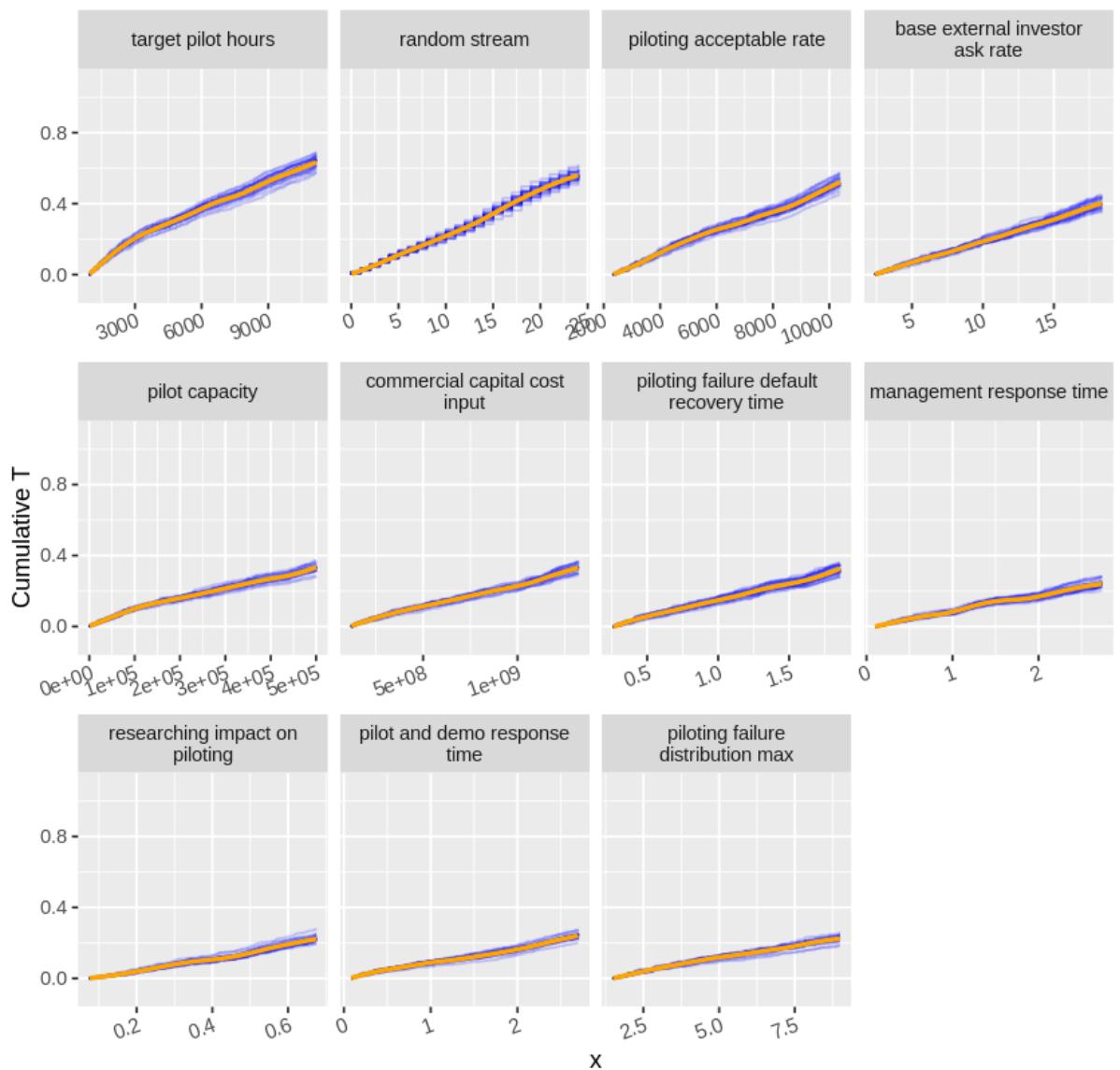
Cumulative Total Sensitivity for predemoing



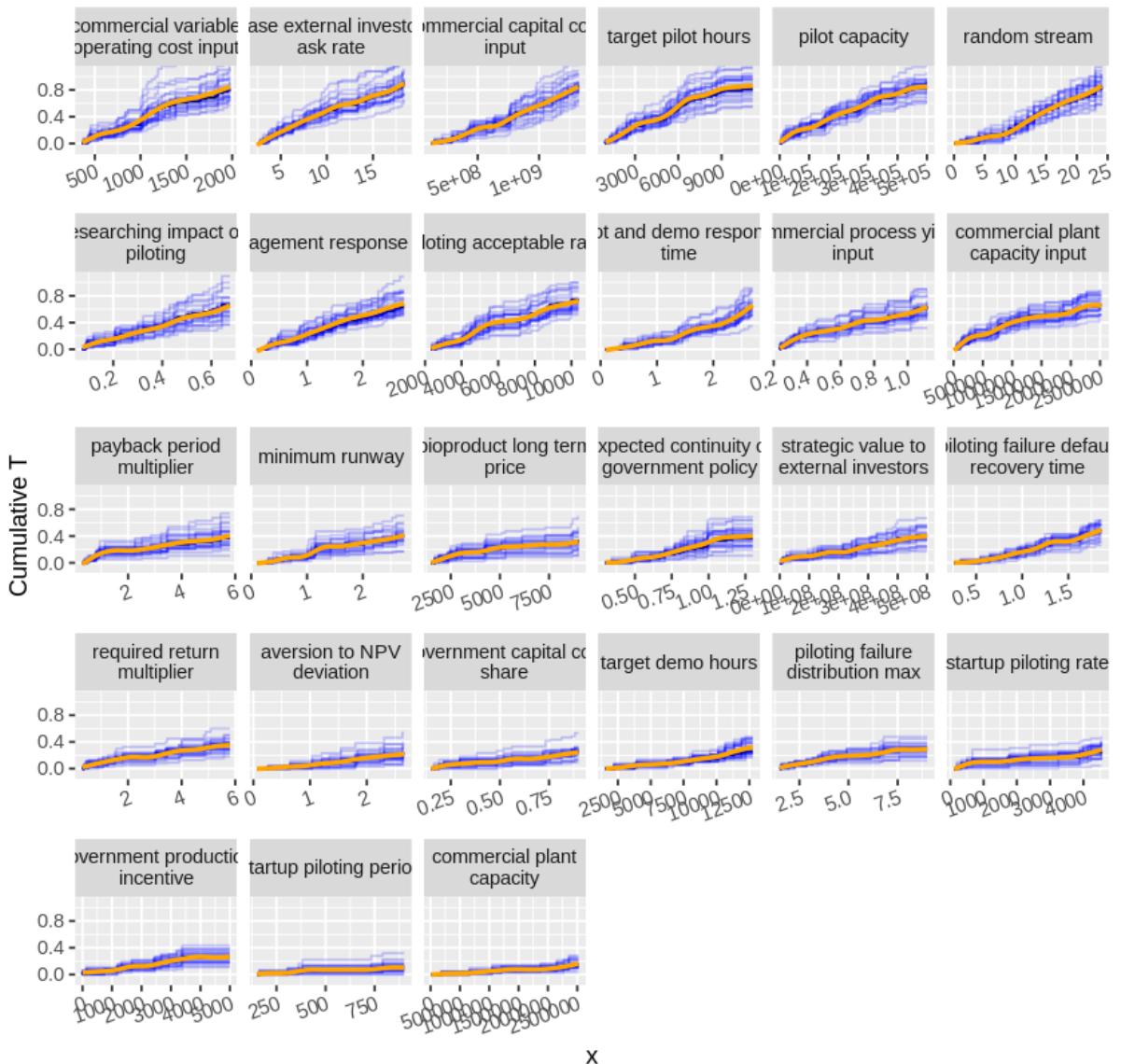
Cumulative Total Sensitivity for demo plant construction



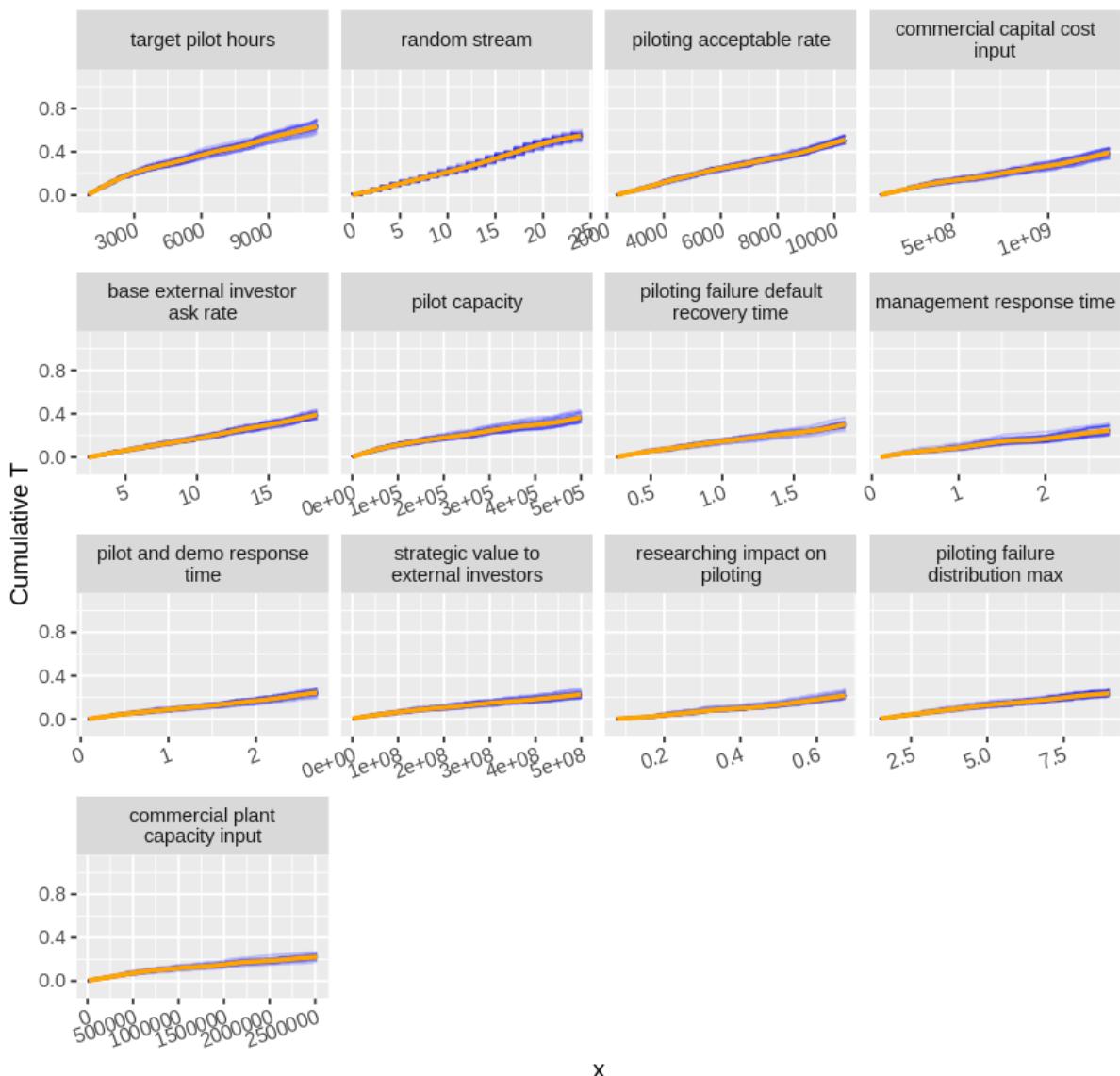
Cumulative Total Sensitivity for demo plant is built



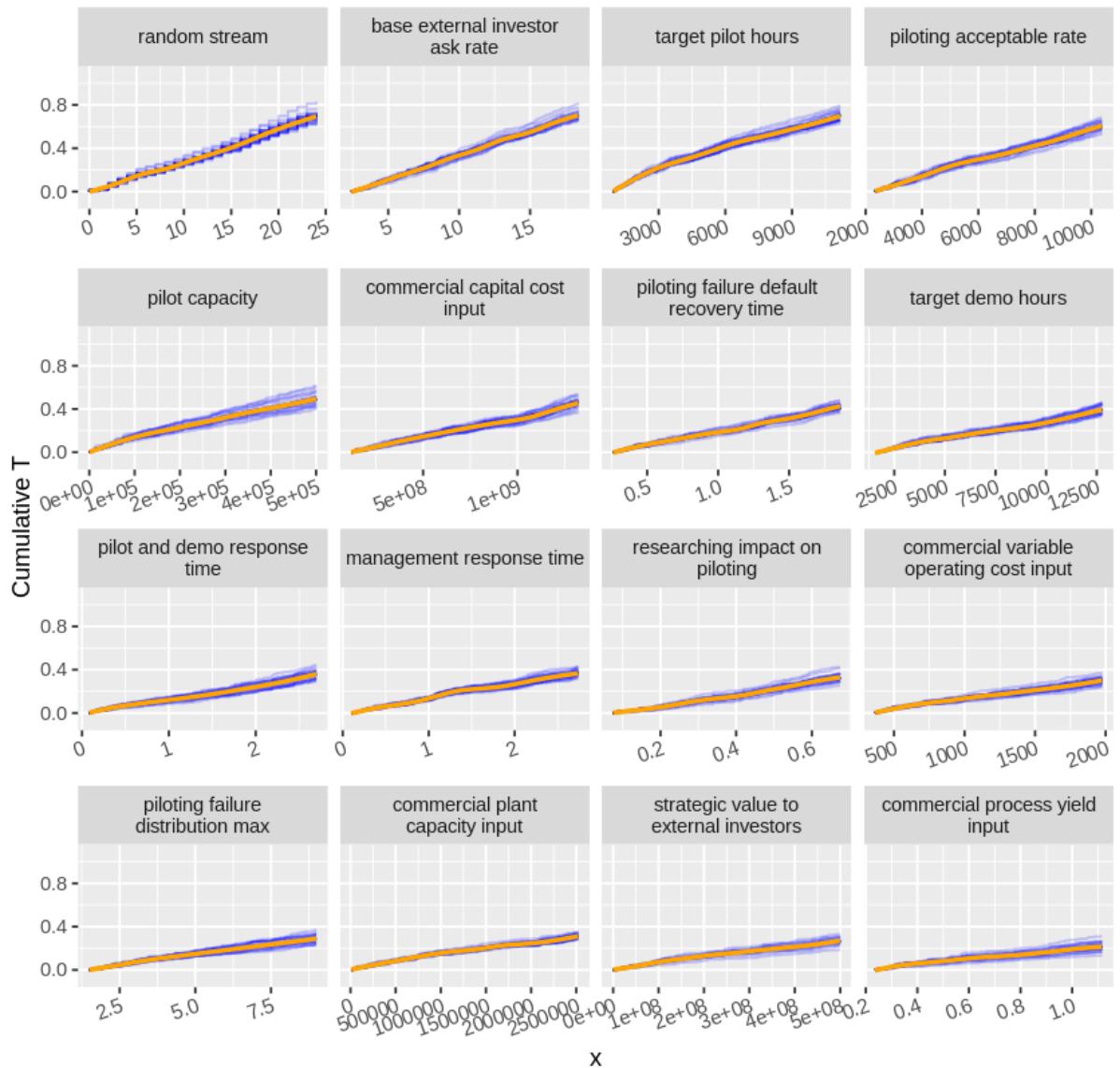
Cumulative Total Sensitivity for regulatory process ongoing



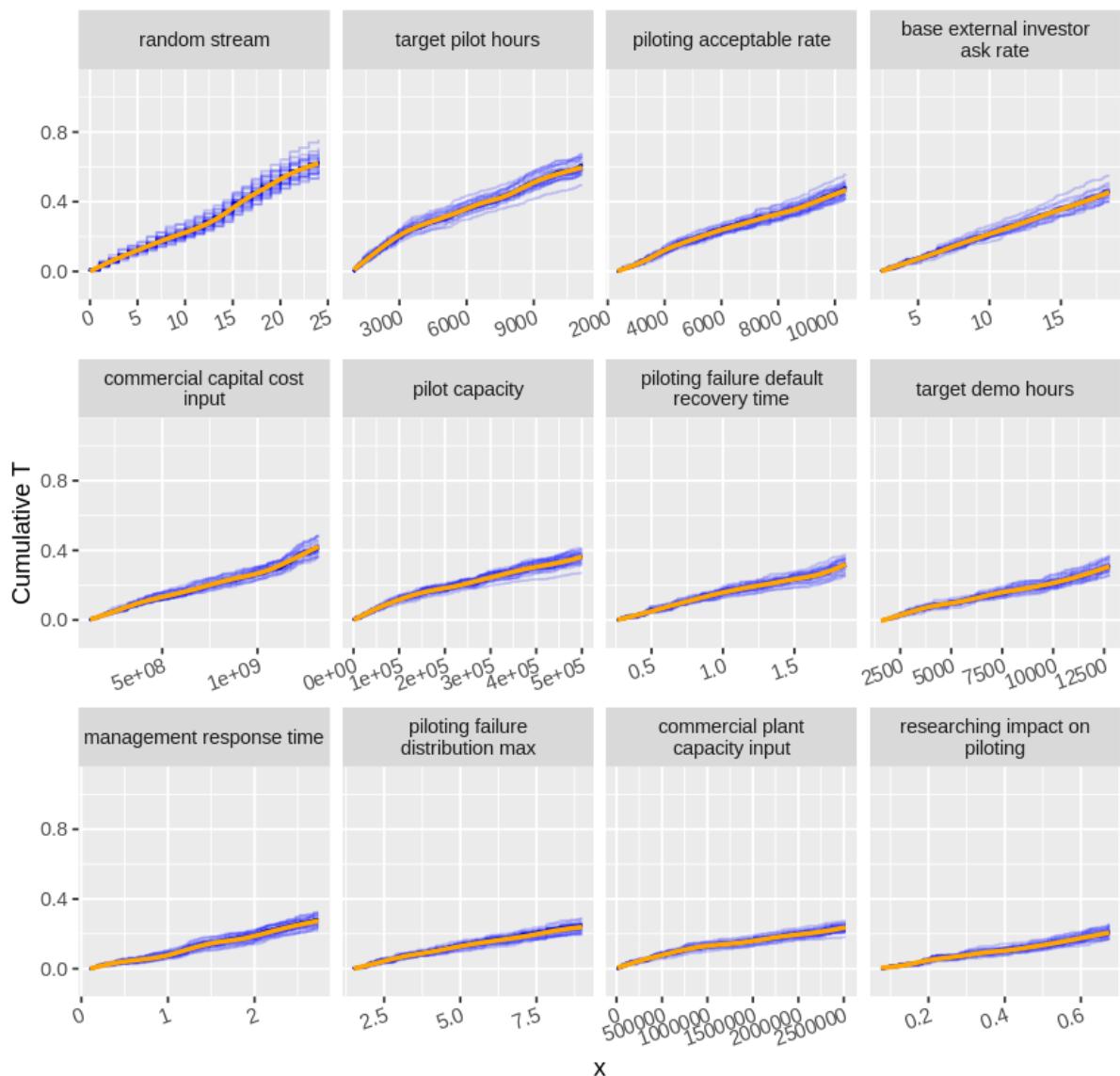
Cumulative Total Sensitivity for startup demoing completed



Cumulative Total Sensitivity for demoing ongoing



Cumulative Total Sensitivity for demoing progress



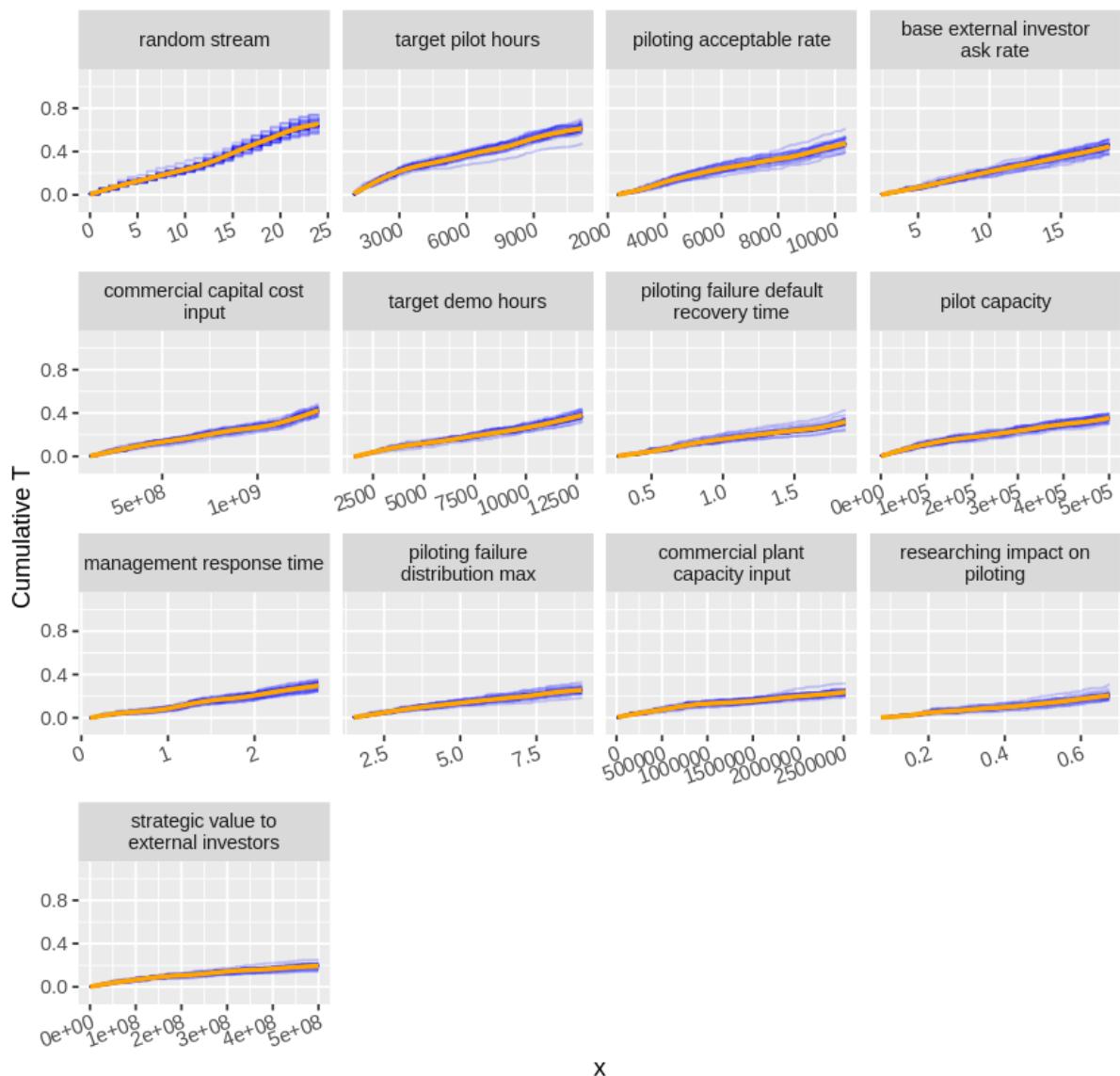
Warning message:

"Removed 5000 rows containing non-finite values (stat_smooth)."

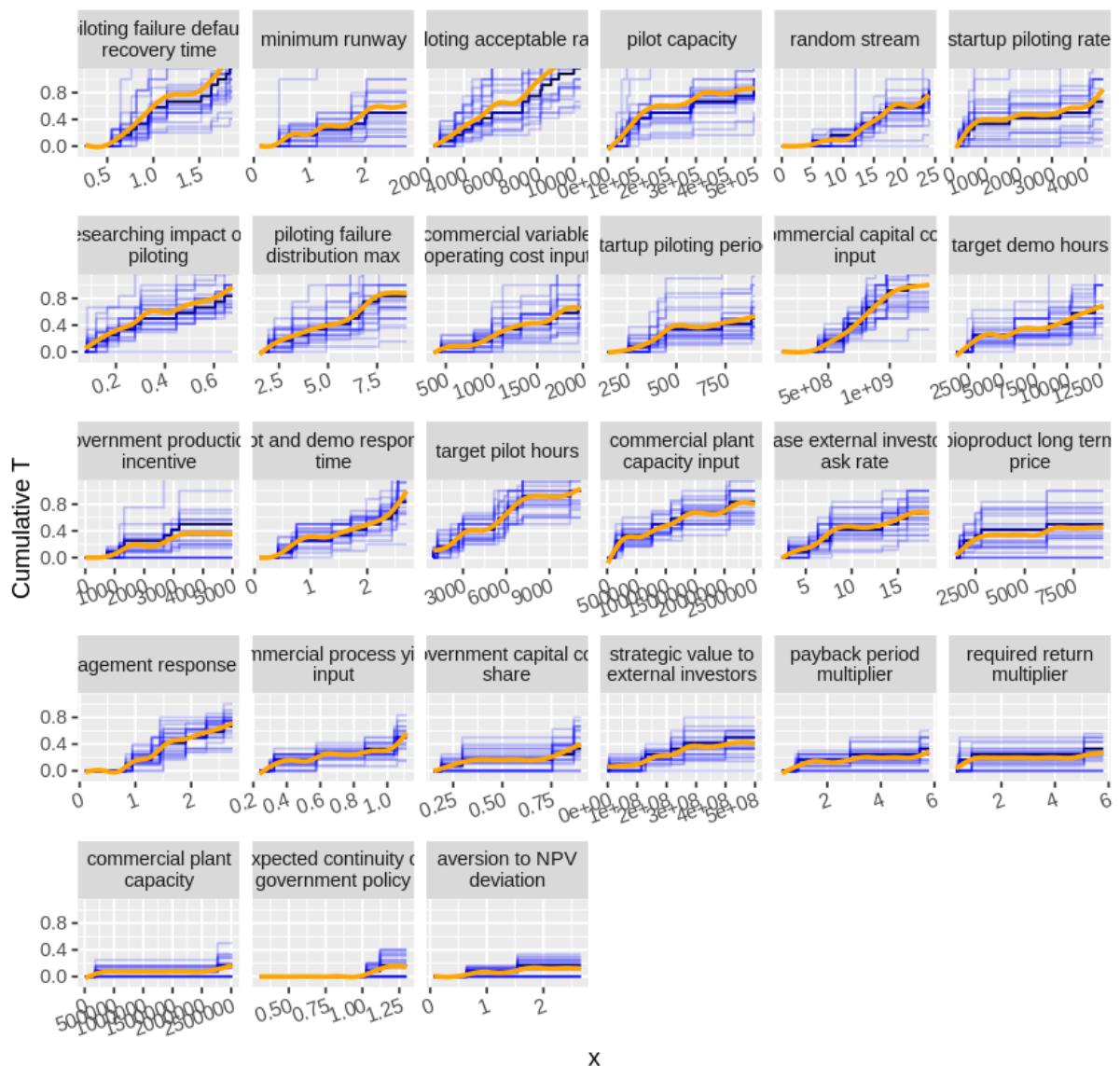
Warning message:

"Removed 5000 rows containing missing values (geom_path)."

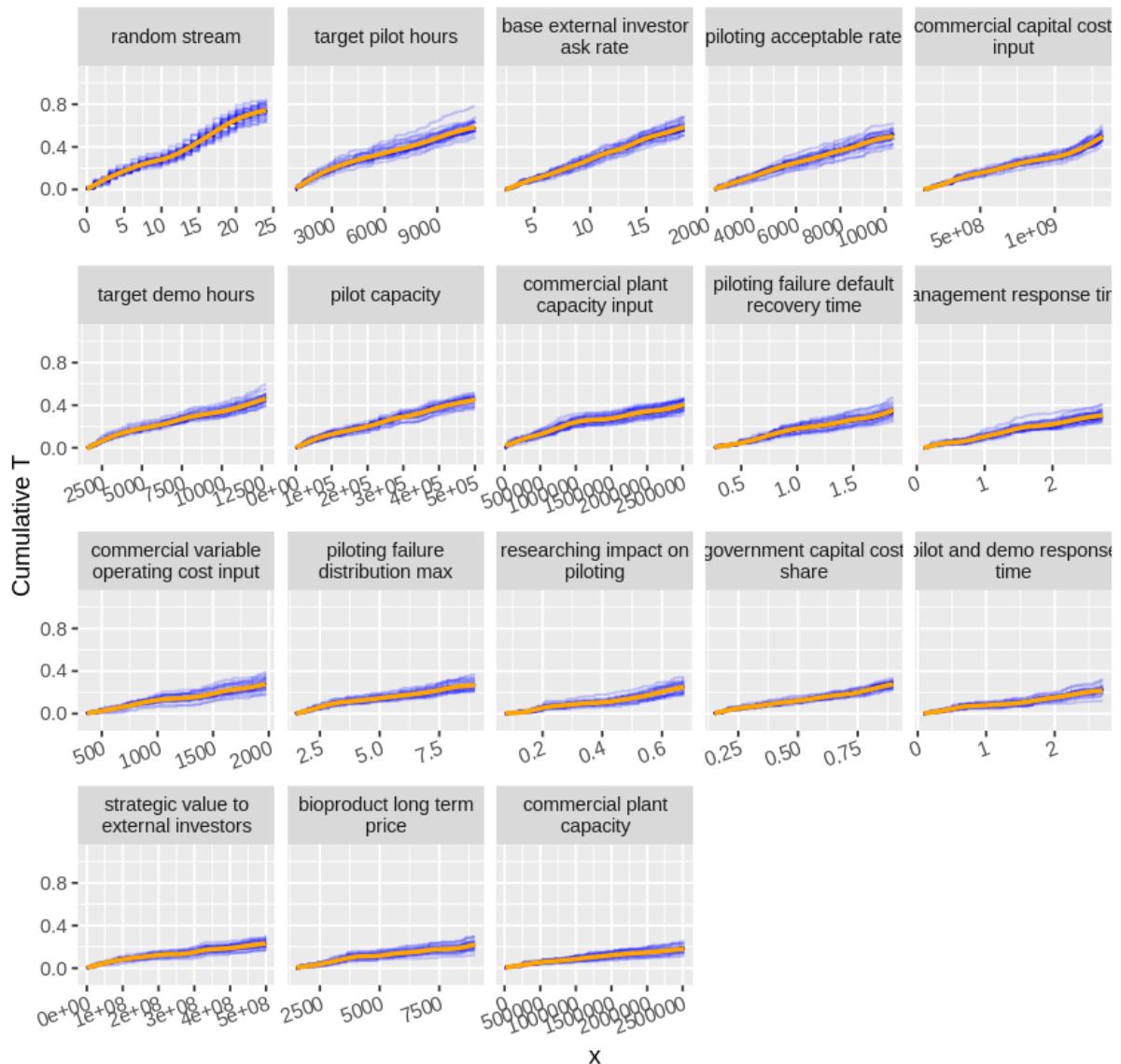
Cumulative Total Sensitivity for demoing complete



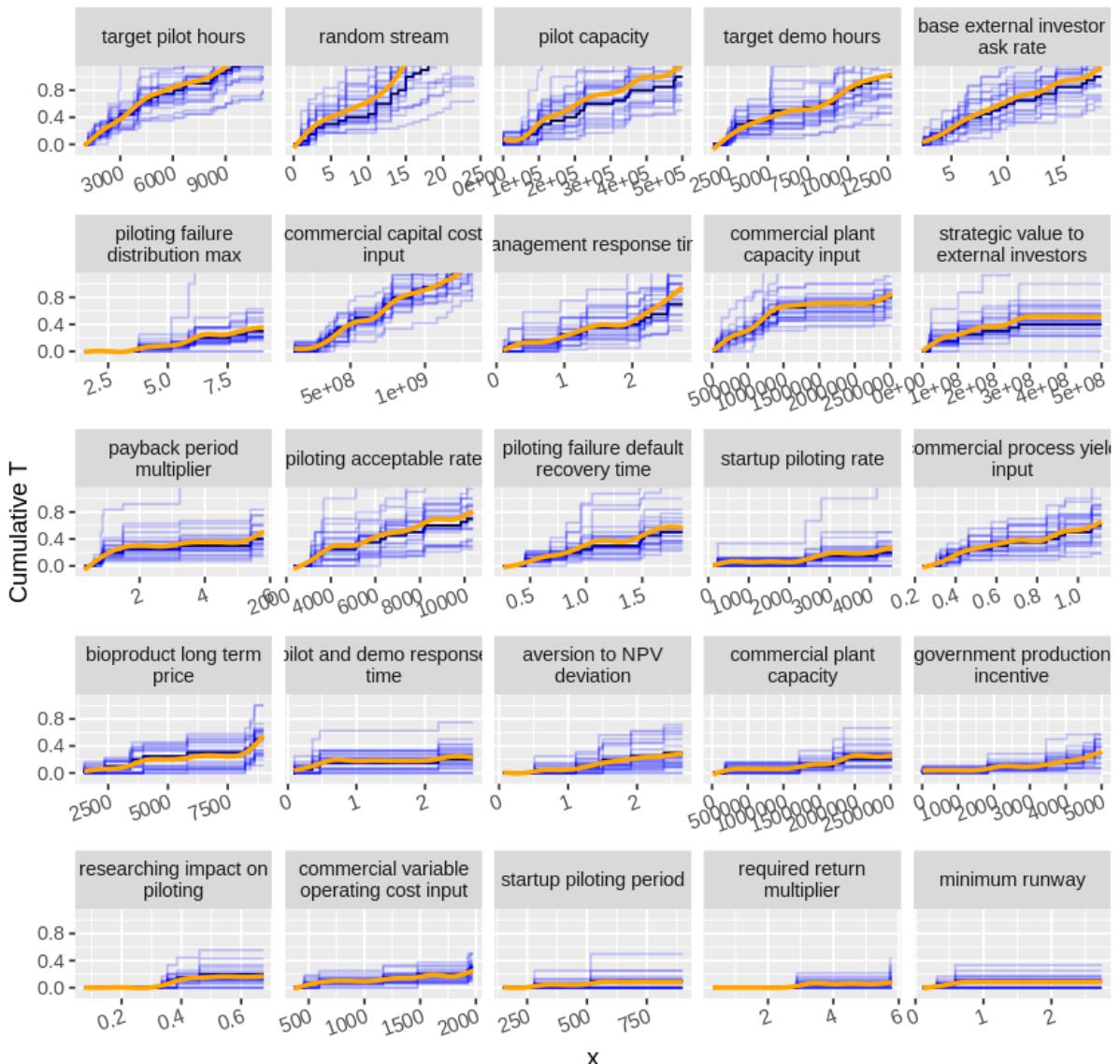
Cumulative Total Sensitivity for regulatory delay



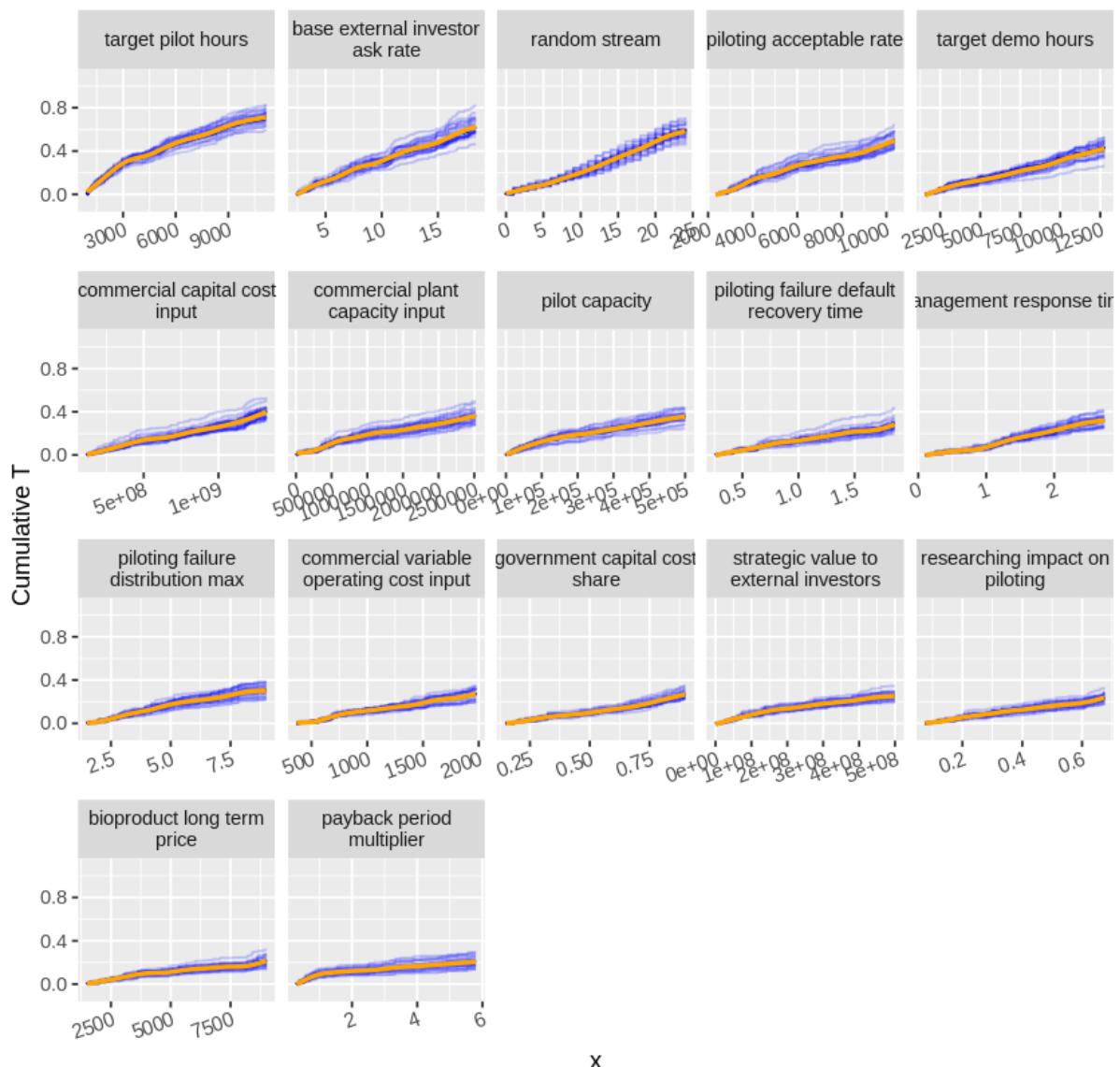
Cumulative Total Sensitivity for precommercial



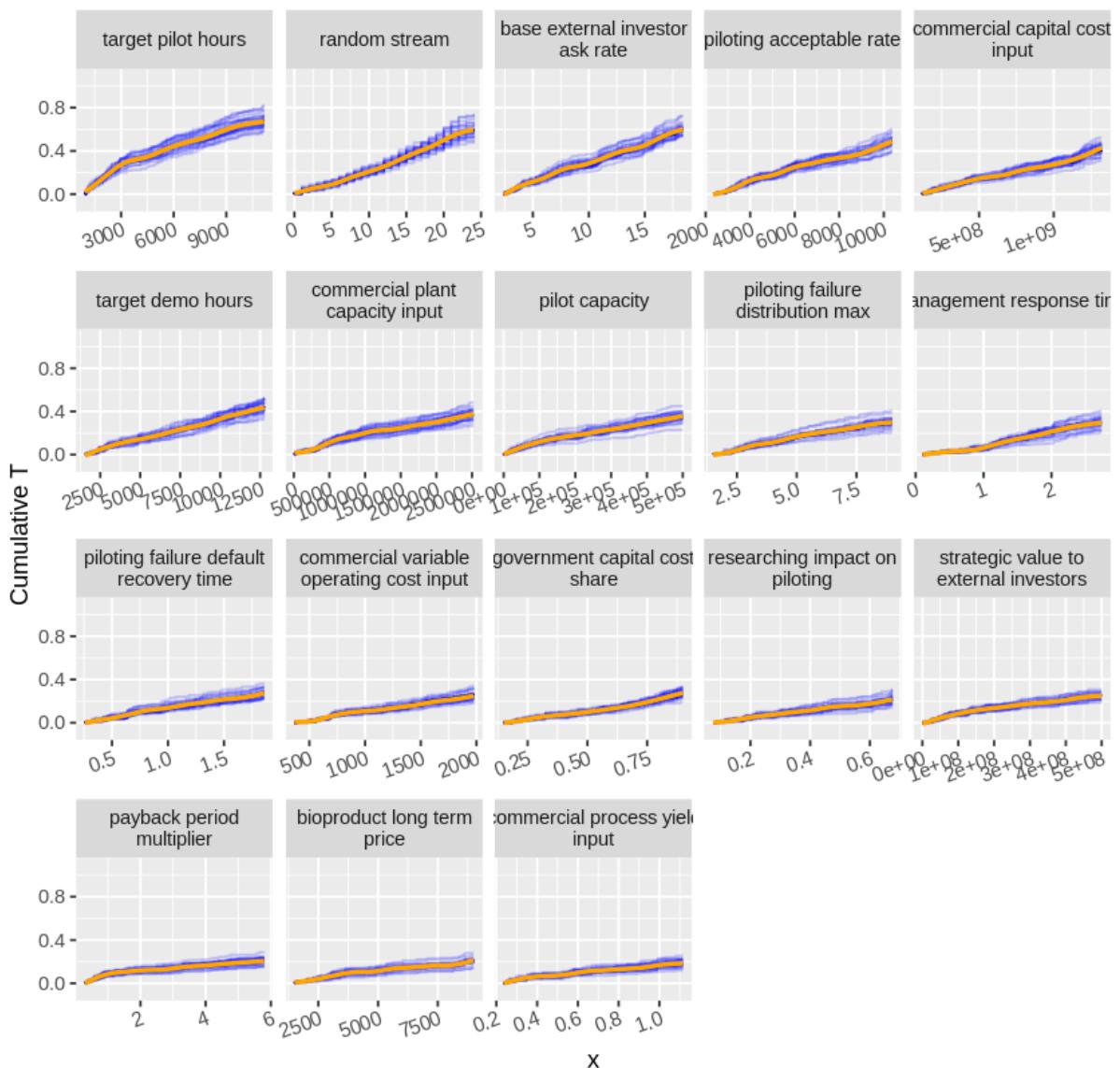
Cumulative Total Sensitivity for commercial plant construction



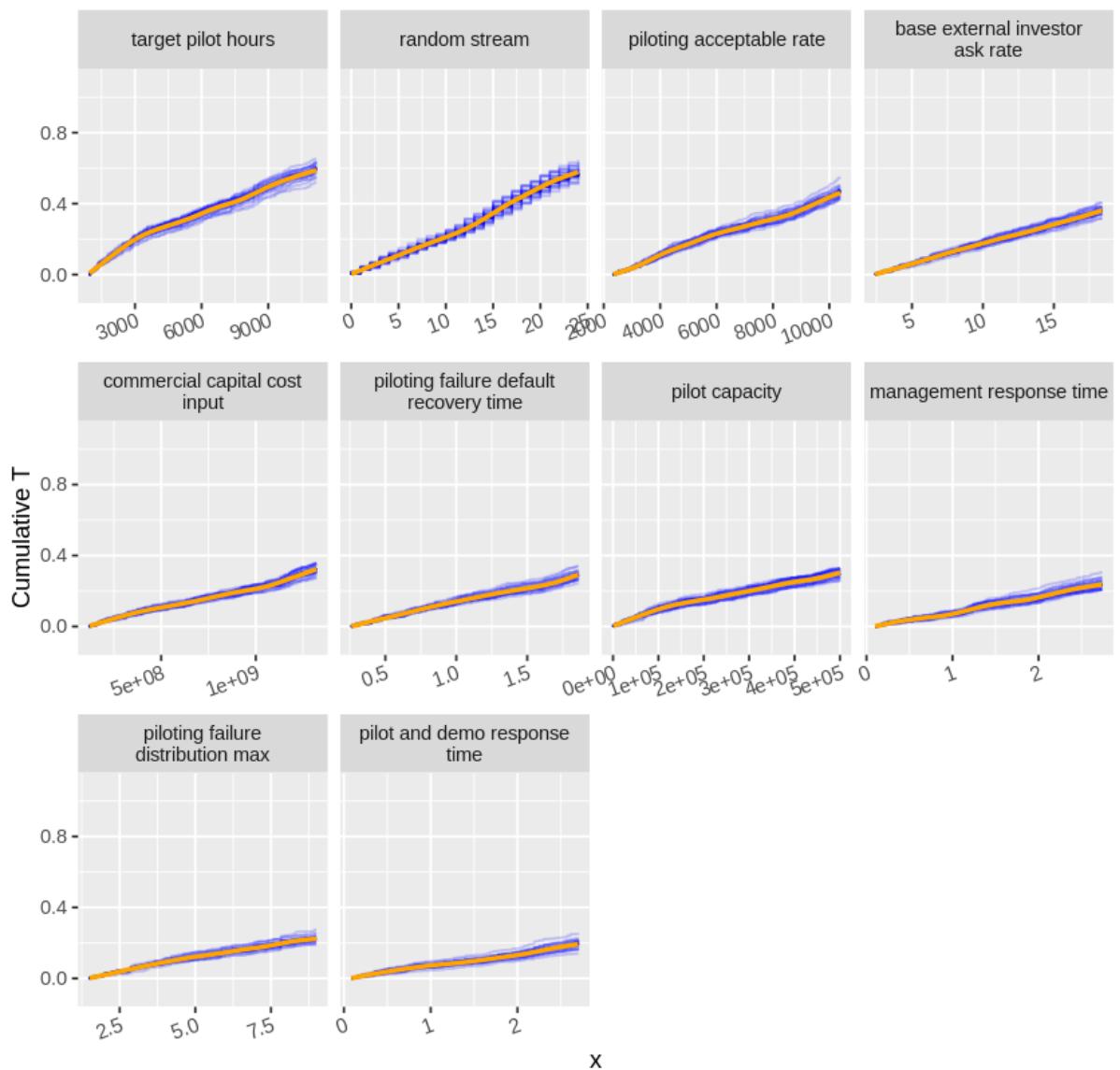
Cumulative Total Sensitivity for commercial plant is built



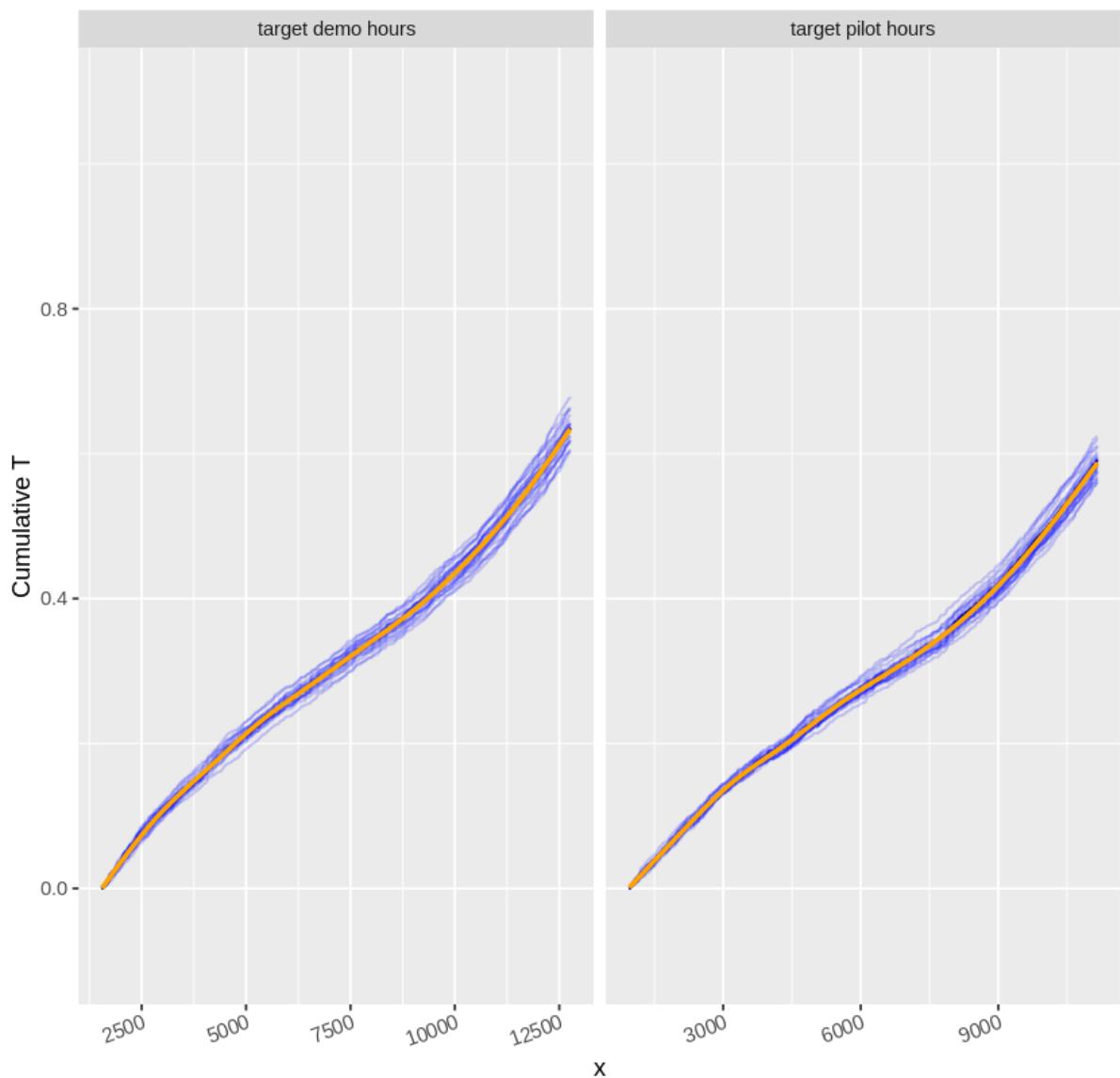
Cumulative Total Sensitivity for commercial plant operation



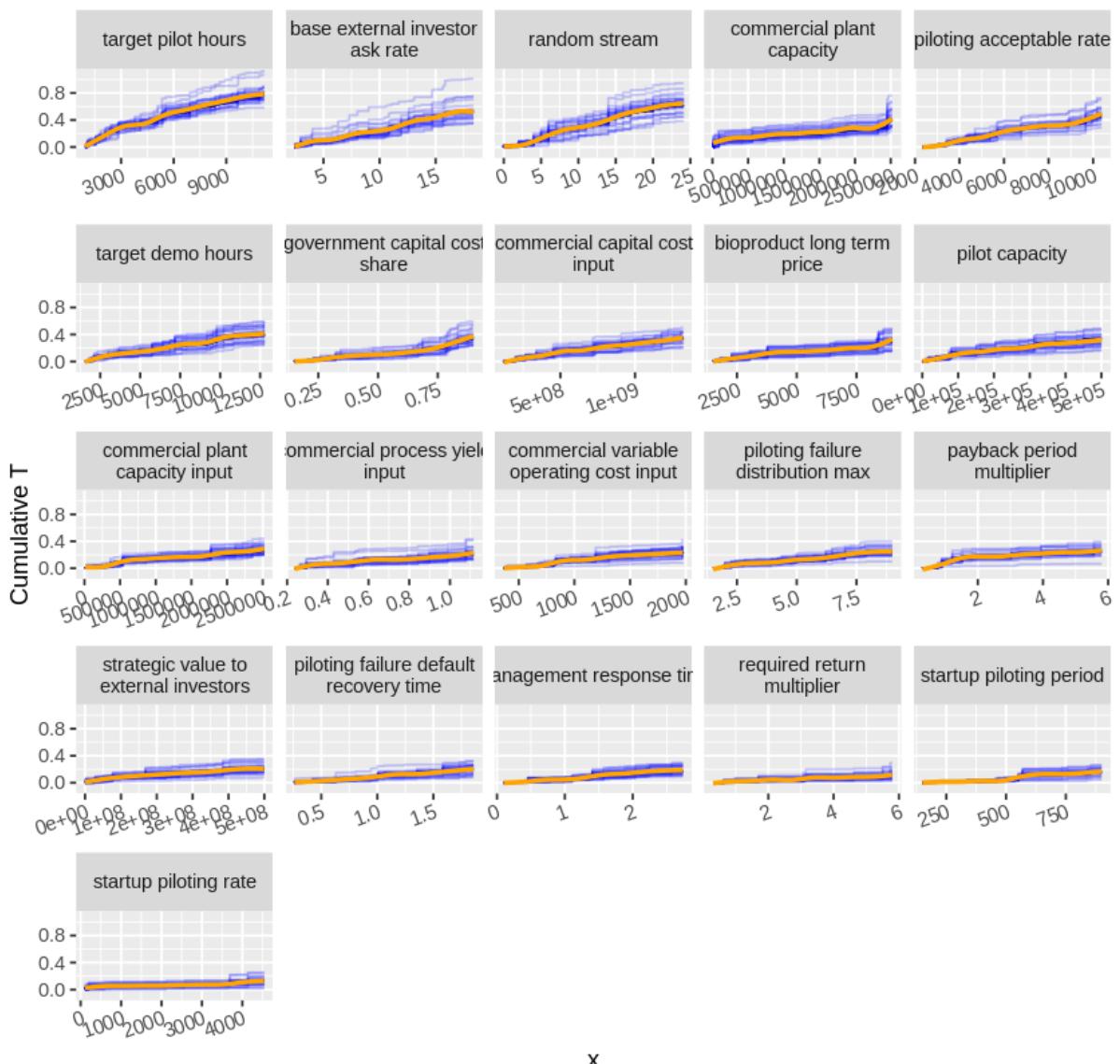
Cumulative Total Sensitivity for technology readiness level



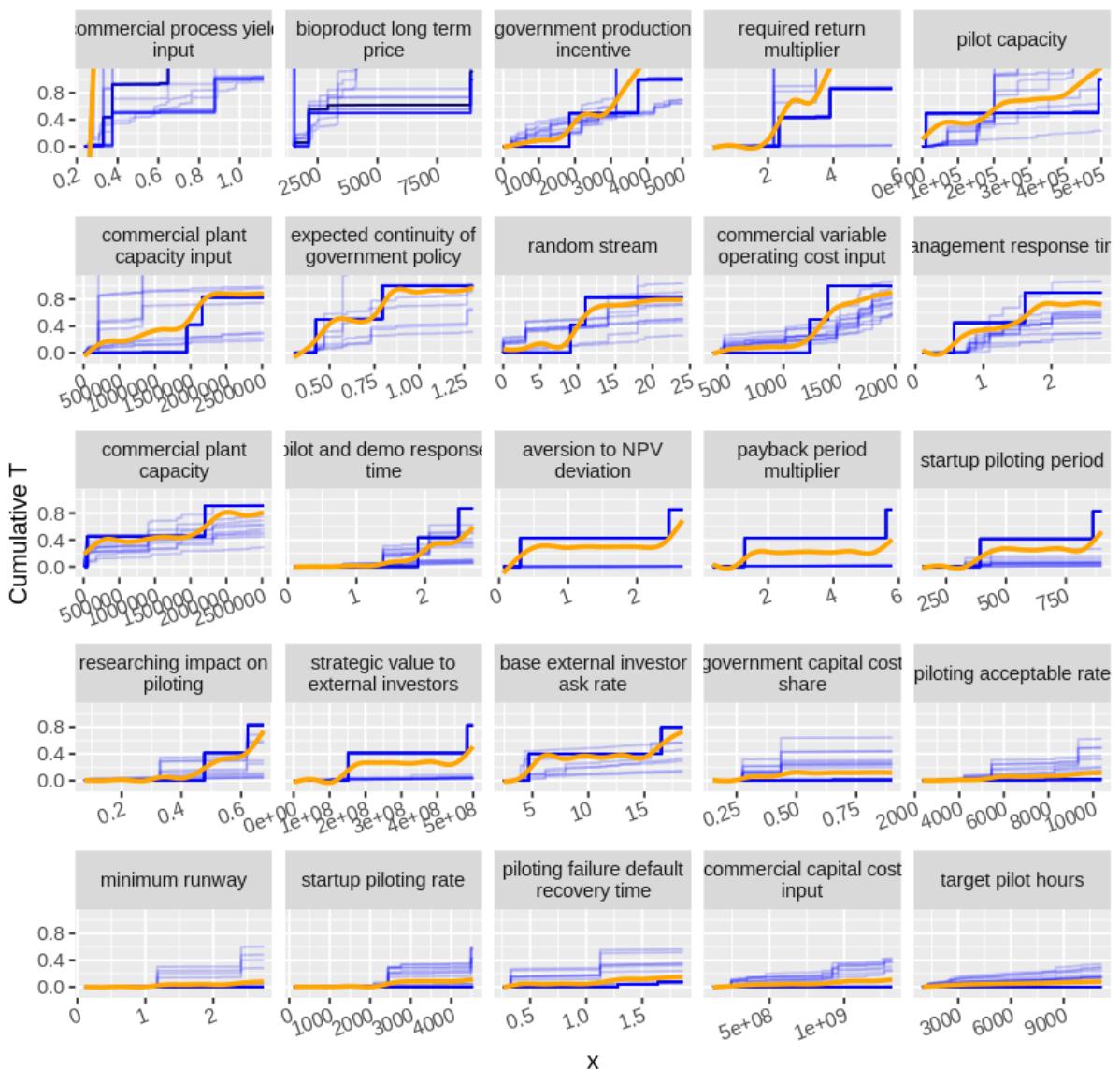
Cumulative Total Sensitivity for stage in progress



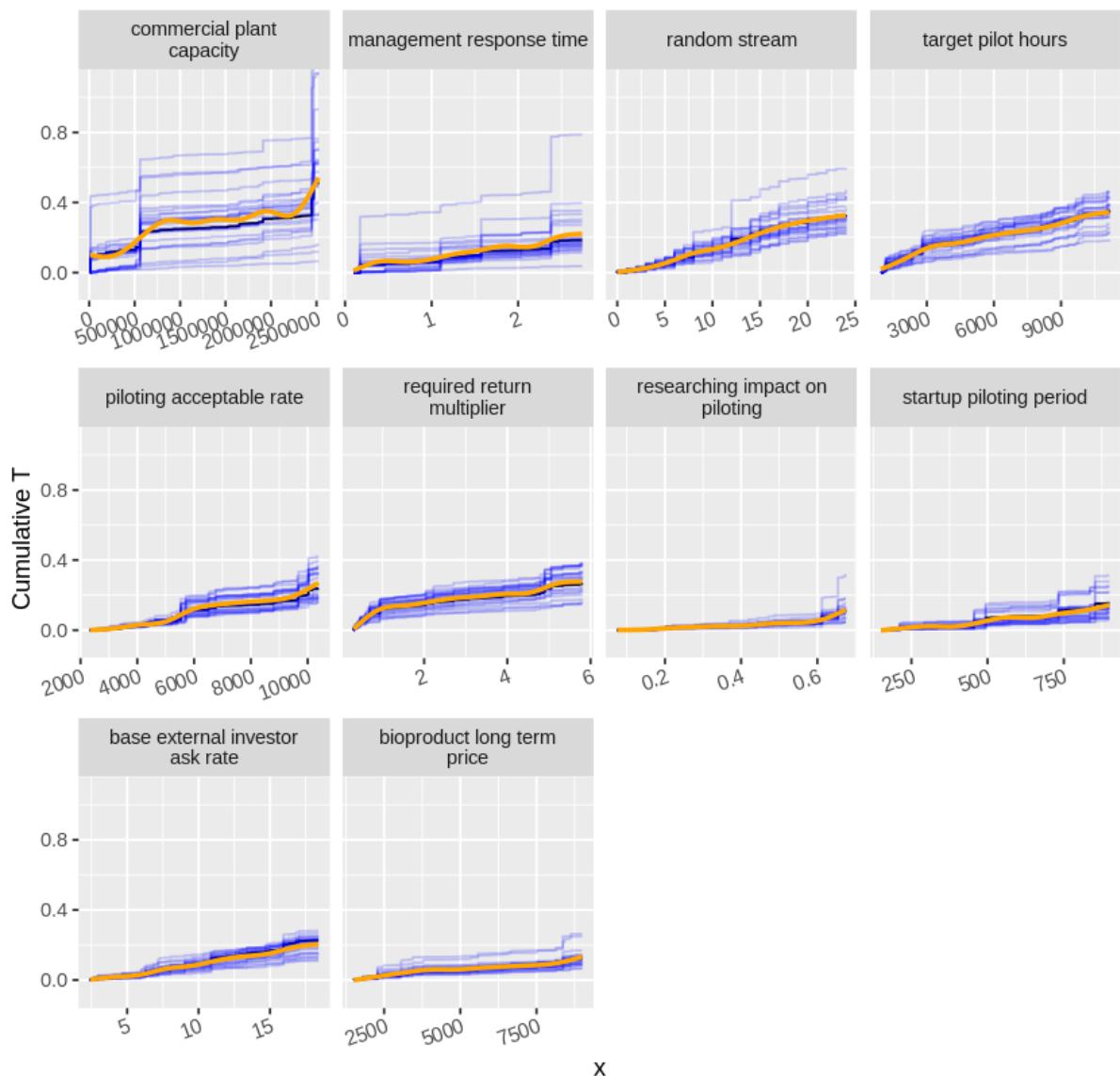
Cumulative Total Sensitivity for BS equity



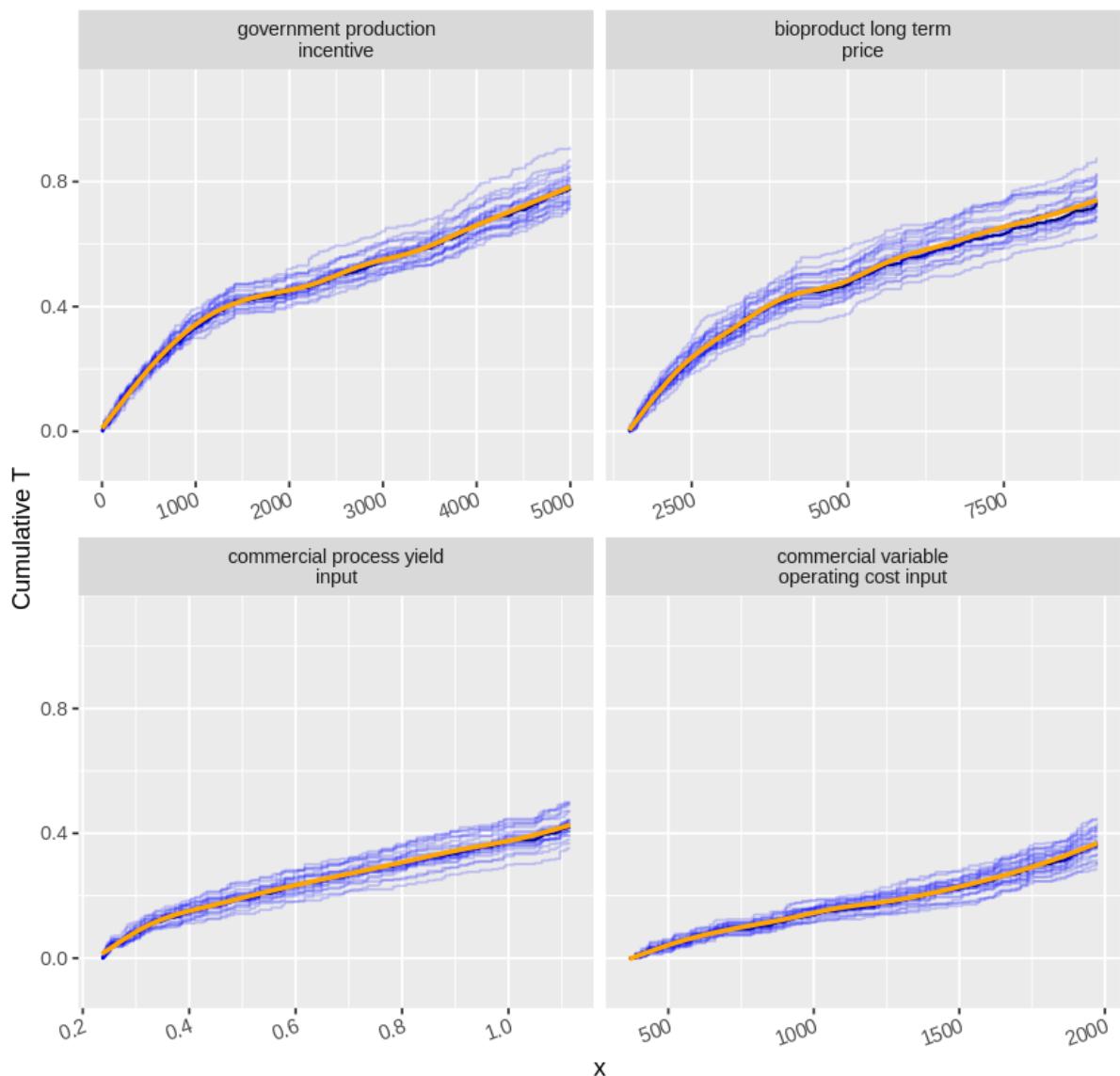
Cumulative Total Sensitivity for payback period



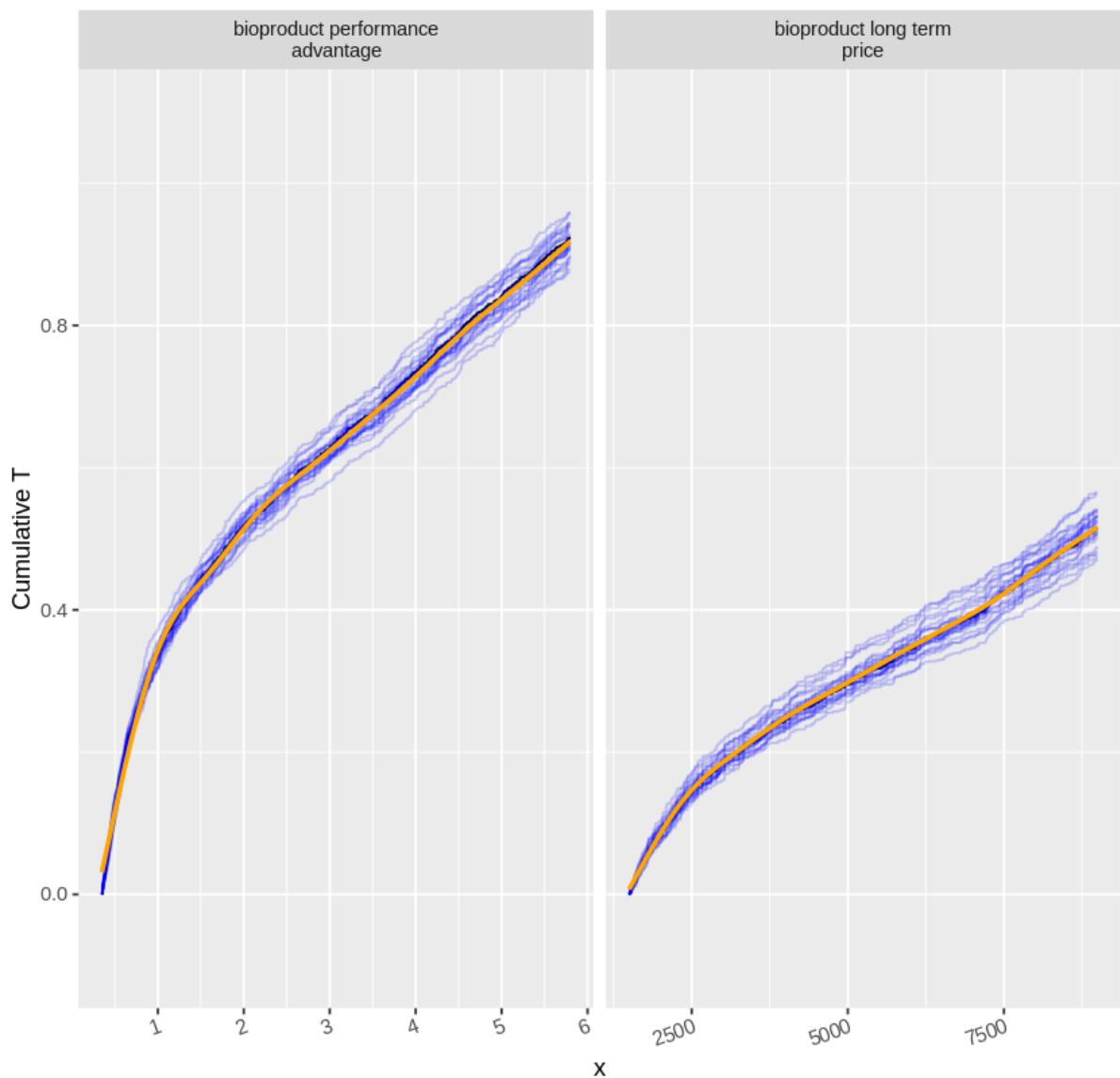
Cumulative Total Sensitivity for NPV at required return



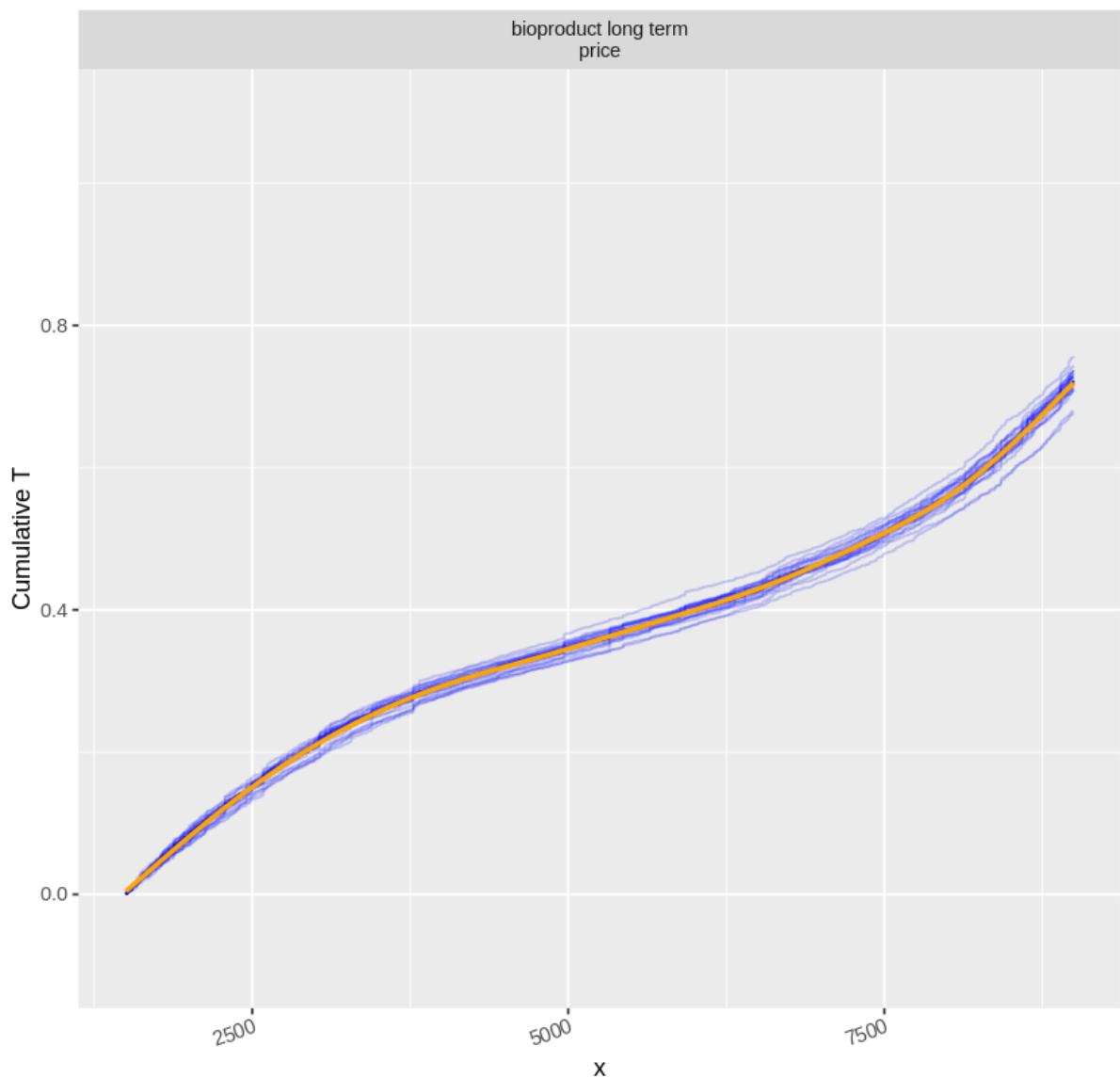
Cumulative Total Sensitivity for profitability indicator



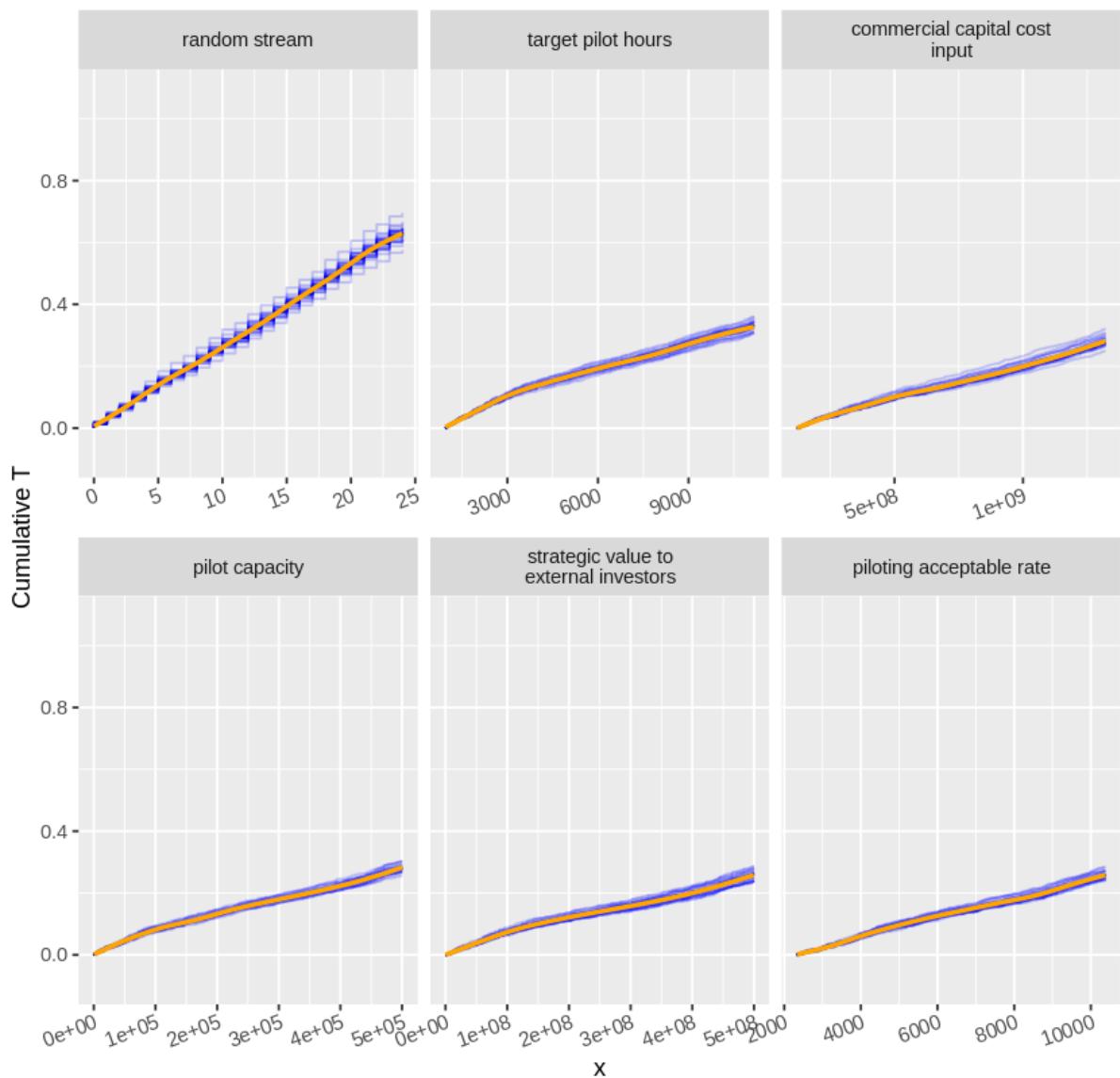
Cumulative Total Sensitivity for bioproduct favorability indicator



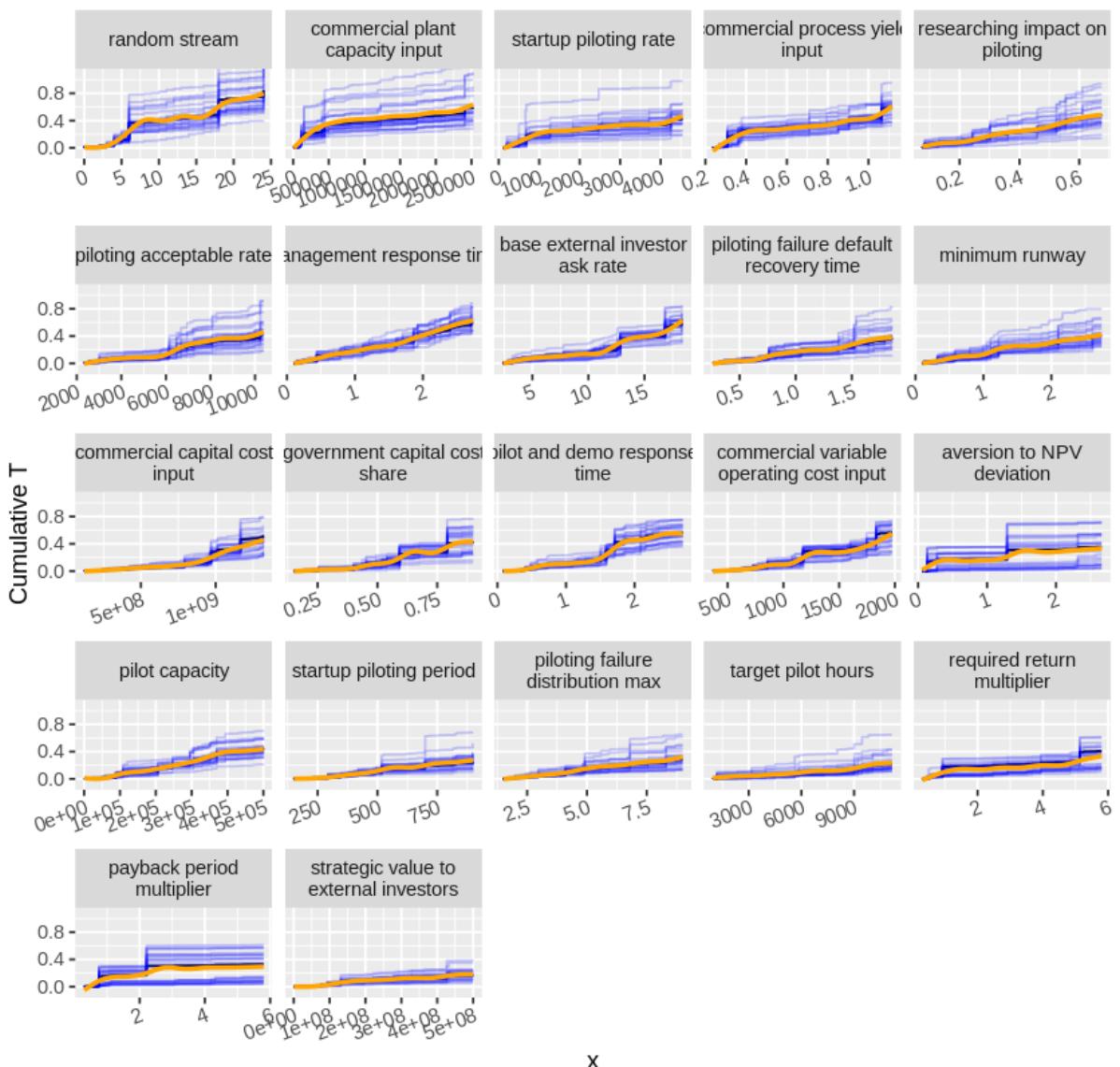
Cumulative Total Sensitivity for long term selling price without green premium after



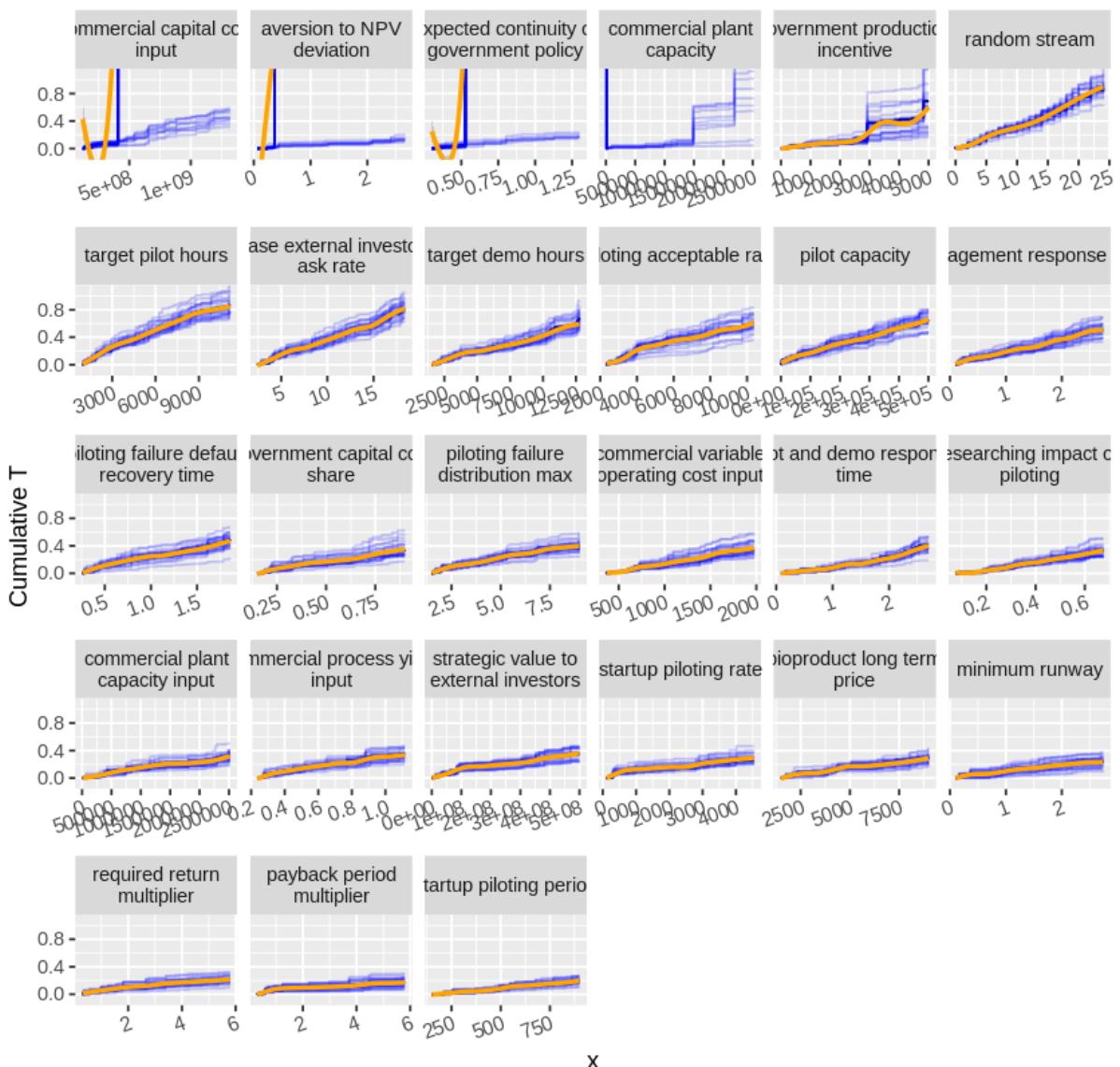
Cumulative Total Sensitivity for in business indicator



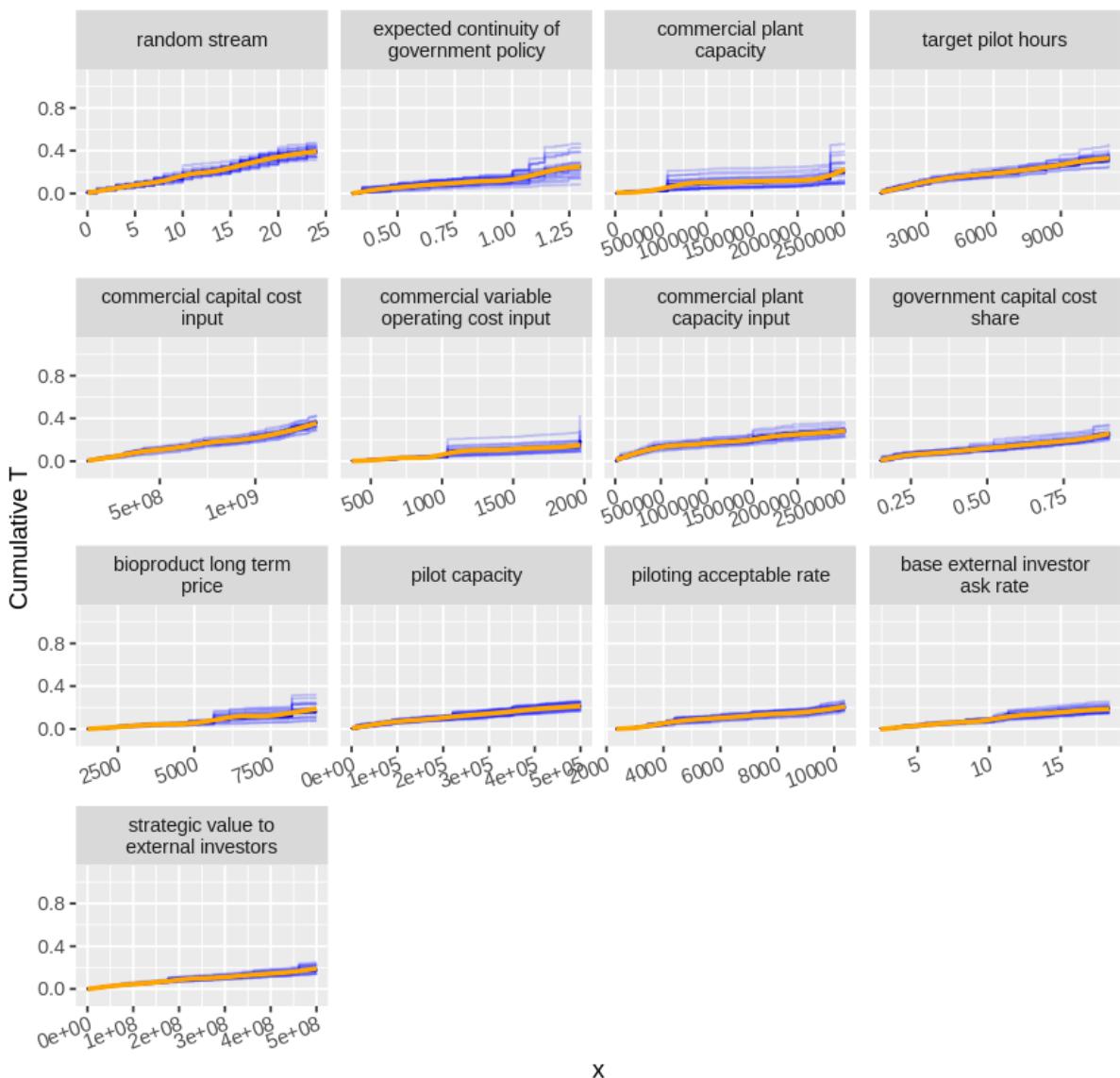
Cumulative Total Sensitivity for investing



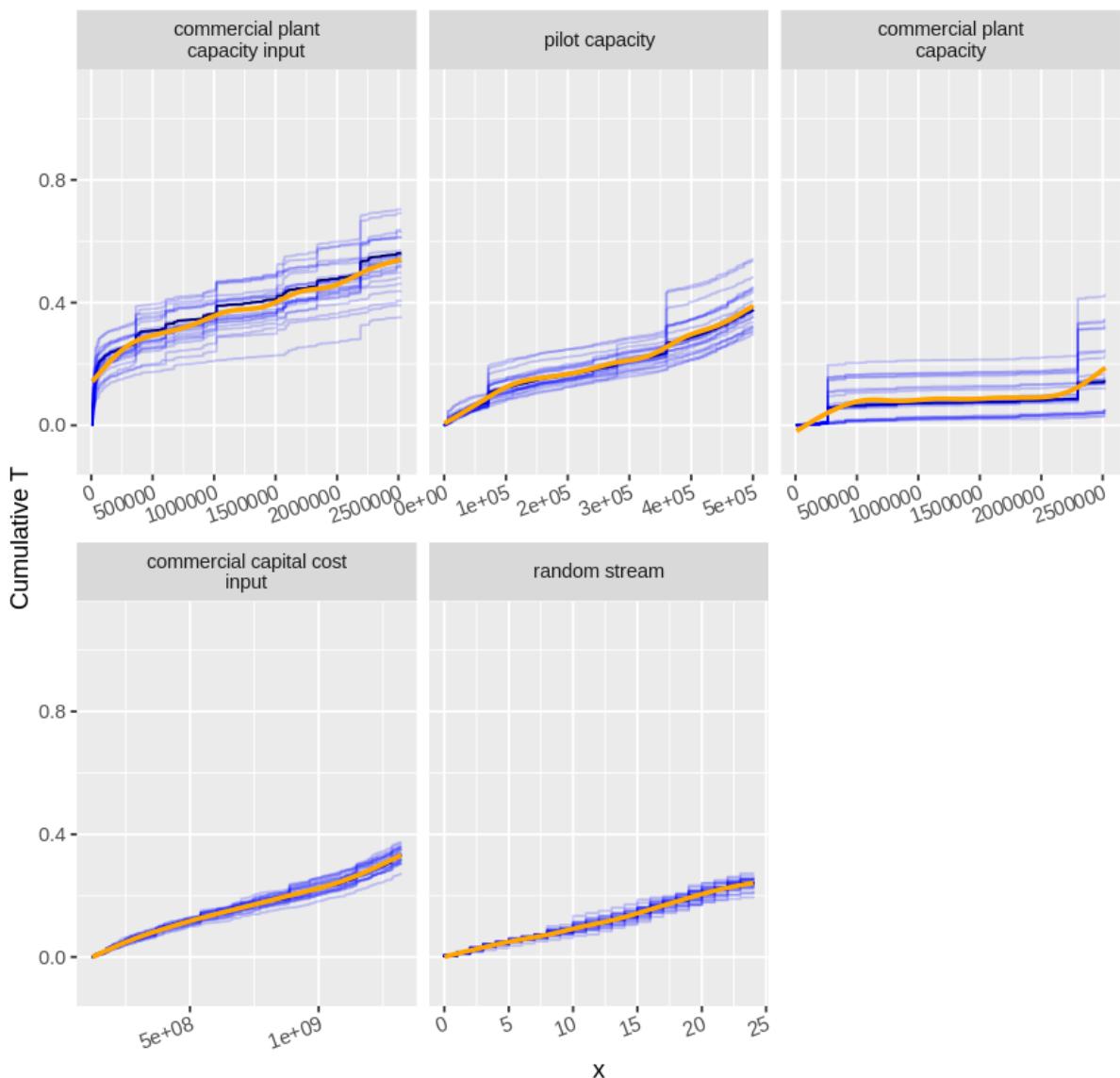
Cumulative Total Sensitivity for granting



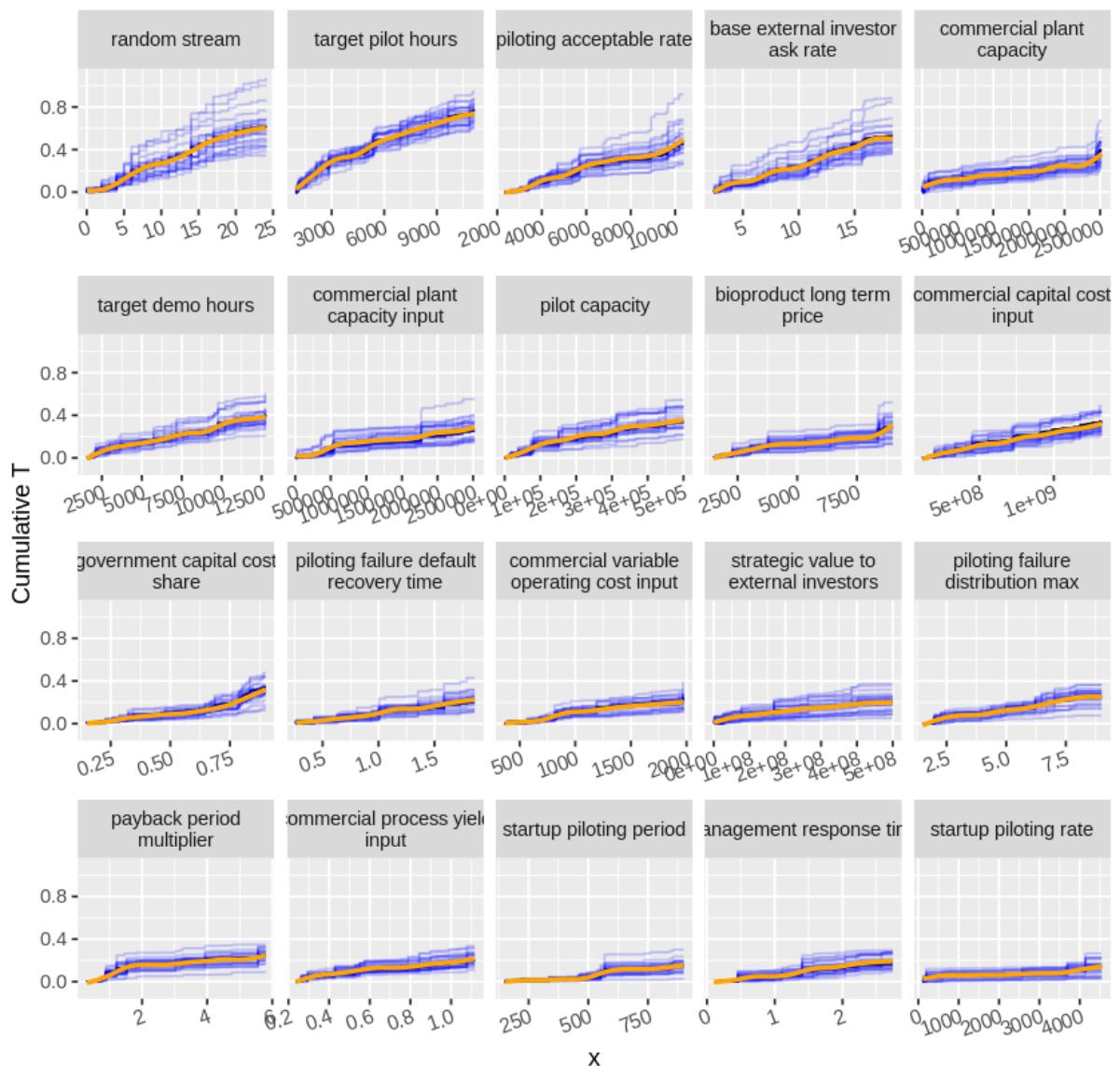
Cumulative Total Sensitivity for Total Government Grants



Cumulative Total Sensitivity for Total Investment



Cumulative Total Sensitivity for Working Capital



Cumulative Total Sensitivity for IS production incentive

