非線形パネルVAR-SPDE-LSTMモデル(精度評価付き)

著者

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メモリ容量の最大化

In [1]:

```
memory.limit(memory.size(max = T))
gc(verbose = getOption("verbose"), reset = T, full = T)
```

```
Warning message in memory.limit(memory.size(max = T)):
" メモリー限界を減らすことができません: 無視しました "
```

32176

A matrix: 2 × 6 of type dbl

	used	(Mb)	gc trigger	(Mb)	max used	(Mb)
Ncells	524108	28.0	1178095	63	524108	28.0
Vcells	961226	7.4	8388608	64	961226	7.4

必要なライブラリの読込

In [2]:

```
load.lib <- c(
 "data.table"     #.csv読込・出力
 , "magrittr"     #前処理
 , "tidyr"        #前処理
 , "dplyr"        #前処理
 , "tidyverse"    #前処理
 , "tseries"      #前処理
 , "urca"         #ADF検定
 , "aTSA"         #共和分検定
 , "plm"          #パネルデータの形成
 , "panelvar"     #パネルVARモデル
 , "Sim.DiffProc" #幾何ブラウン運動
 , "ggplot2"      #可視化
 , "gridExtra"    #グラフの集約
 , "qgraph"       #相関行列の可視化
 , "tsbox"        #ts_df関数の利用
 , "keras"        #LSTMによる幾何ブラウン運動の精度評価
 , "tensorflow"   #LSTMによる幾何ブラウン運動の精度評価
 , "vars"         #関数定義に用いる(以下、同じ)。
 , "NlinTS"
 , "tsDyn"
)
install.lib <- load.lib[!load.lib %in% installed.packages()]
for(lib in install.lib) install.packages(lib,dependencies = T)
sapply(load.lib,require,character = T)
#LSTMによる幾何ブラウン運動の精度評価
install_tensorflow(gpu = TRUE) #GPUの利用
```

```
Loading required package: lmtest


Attaching package: 'vars'


The following object is masked from 'package:panelvar':

    stability


The following object is masked from 'package:aTSA':

    arch.test


Loading required package: NlinTS

Warning message:
```

関数定義

- 対数差分系列
- プロビット写像
- 偏グレンジャー因果性検定と非直交化インパルス応答関数
- ADF検定
- 標本分散
- 時系列プロット
- LSTM(Long Short Term Memory)

In [3]:
```
#対数差分系列に変換する。
diff.log <- function(x) {
  y <- diff(log(x))
  return(y)
}
#プロビット写像
probit <- function(x) {
  y <- c(exp(((-x^2)/2))/sqrt(2 * pi))
  return(y)
}
#偏グレンジャー因果性検定と非直交化インパルス応答関数
ts <- function(y1, y2) {
  temp  <- cbind(y1, y2) %>% as.data.frame
  model <- VAR(temp, p = 2, type = "both", ic = "AIC")
  wk_result_1  <- causality(model, cause = "y1")
  wk_result_2  <- causality(model, cause = "y2")
  granger      <- list(wk_result_1, wk_result_2)
  impulse_1 <- irf(model, impulse = "y1", response = "y2", boot = F)
  impulse_2 <- irf(model, impulse = "y2", response = "y1", boot = F)
  imp <- list(impulse_1, impulse_2)
  result <- list(granger, imp)
  return(result)
}
#ADF検定
ADF <- function(x) {
  result <- ur.df(x,type = c("drift"), lags = 1) %>%
    summary
  return(result)
}
#標本分散
sigma <- function(x) {
  result <- var(x)*(length(x)-1)/length(x)
  return(result)
}
#時系列プロット
fig <- function(data, y, title, label) {
  data %>%
    ggplot(aes(x = time, y = y)) +
    geom_point() +
    geom_line() +
    ggtitle(title) +
    labs(x = "年", y =  label)
}
#LSTM(Long Short Term Memory)の前処理
#時系列データts_dfをwindowで指定した長さ毎に区切って訓練用のデータを生成する。
LSTM <- function(ts_df, window, rm.na = F) {
  data.x = NULL
  data.y = NULL
  n = dim(ts_df)[2]
  for(i in 1:n){
    ts_x = ts_df[,i]
    for(j in 1:(length(ts_x)-window)){
      if(rm.na){
        tmp.x = ts_x[1:window + j -1]
        tmp.y = ts_x[1:window + j -1]
        if(sum(c(is.na(tmp.x),is.na(tmp.y))) == 0){
          data.x = rbind(data.x,ts_x[1:window + j -1])
          data.y = rbind(data.y,ts_x[window + j])
        }
      }else{
        data.x = rbind(data.x,ts_x[1:window + j -1])
        data.y = rbind(data.y,ts_x[window + j])
      }
    }
  }
  data <- list(x = array_reshape(data.x,c(dim(data.x),1)),
               y = data.y)
  scale = max(ts_df, na.rm = T)
  x = data$x / scale
  y = data$y / scale
  lstm <- keras_model_sequential()
  lstm %>%
    layer_lstm(units = 64,input_shape = c(dim(x)[2],1)) %>%
    layer_dropout(rate = 0.4) %>%
    layer_dense(units = 1)
  lstm %>% compile(loss = "mean_squared_error",
                   optimizer = optimizer_adam(),
                   metrics = "accuracy")
  lstm %>% fit(x,y,
               epochs = 1000,batch_size = 10, validation_split = 0.2)
  i = 1
  test_x = ts_df[,i]
  test_x = data$x
  scale=max(ts_df,na.rm = T)
  test_x = test_x/scale
  pred_x = lstm %>%
    predict(test_x)
  ts.plot(ts_df[,i]/scale->a,ylim = c(min(c(a,pred_x)), max(c(a,pred_x))), ylab = "検証値")
  lines(c(rep(NA,window),pred_x), col = 2)
}
```

ローデータの目視確認

- 読込
- 要約統計量を求める。

In [4]:
```
#読込
raw_data <- fread("./0_input/raw_data.csv") %>%
  as.data.frame
raw_data
```

```
Warning message in require_bit64_if_needed(ans):
"Some columns are type 'integer64' but package bit64 is not installed. Those columns will print as strange looking floating point data. There is no need t
install.packages('bit64') to obtain the integer64 print method and print the data again."
```

A data.frame: 29 × 13

id	time	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11
<int>	<int>	<dbl>	<dbl>	<int>	<dbl>	<int64>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<int>
0	1986	11.36838	1111250	0	20.90	1.212152e-313	42.4	85.9	2.6	217.71013	58.594	0
0	1987	11.91077	1111019	0	24.12	1.437787e-313	41.9	85.9	2.8	251.03609	58.594	0
0	1988	12.58026	1186750	0	18.37	1.734345e-313	40.4	86.5	2.8	348.65896	58.594	0
0	1989	13.02217	1216857	0	22.40	1.735299e-313	38.7	88.5	2.5	439.72734	58.594	0
0	1990	13.54005	1304676	0	27.67	1.772752e-313	36.8	91.2	2.3	261.49901	53.711	0
0	1991	13.73636	1318934	1	23.65	1.974477e-313	36.2	94.3	2.1	243.73033	53.711	0
0	1992	13.85659	1330643	0	22.79	2.087208e-313	36.9	95.8	2.1	176.66962	43.640	1
0	1993	14.00667	1333073	0	19.51	2.313130e-313	39.9	97.1	2.2	179.37425	43.640	0
0	1994	14.50500	1385835	0	18.97	2.530688e-313	41.1	97.7	2.5	201.87369	43.640	1
0	1995	14.96408	1421641	1	18.69	2.772627e-313	43.6	97.6	2.9	203.56711	43.640	0
0	1996	15.20326	1424113	0	22.65	2.444392e-313	46.3	97.7	3.2	198.17144	47.600	0
0	1997	15.31663	1414397	0	22.31	2.234803e-313	48.4	99.5	3.4	153.35417	47.600	1
0	1998	15.11348	1371363	0	15.90	2.039227e-313	56.1	100.1	3.4	138.28342	47.600	0
0	1999	15.48801	1399009	1	22.42	2.265293e-313	63.5	99.8	4.1	189.72285	47.600	0
0	2000	15.65519	1406195	0	35.48	2.412343e-313	69.5	99.1	4.7	139.10888	48.542	0
0	2001	15.45515	1387952	1	31.80	2.130494e-313	75.6	98.4	4.7	107.14045	48.542	0
0	2002	15.68053	1422453	0	32.94	2.051602e-313	81.8	97.5	5.0	87.98923	48.542	0
1	2003	15.53167	1428102	0	36.30	2.232162e-313	88.2	97.2	5.4	109.84198	49.375	0
0	2004	15.73810	1427399	1	44.38	2.440000e-313	95.8	97.2	5.3	118.19712	49.375	0
0	2005	15.67054	1439905	0	60.88	2.417166e-313	100.2	97.0	4.7	166.26863	61.667	1
0	2006	15.71379	1425899	0	71.49	2.302782e-313	100.5	97.2	4.4	177.22047	61.667	0
1	2007	15.44623	1461356	1	74.52	2.302205e-313	102.0	97.2	4.1	157.48745	61.667	0
0	2008	14.35917	1385165	0	94.32	2.560759e-313	107.2	98.6	3.9	89.85355	61.667	1
0	2009	14.08942	1290244	0	64.02	2.659101e-313	120.7	97.2	4.0	108.50247	24.792	0
1	2010	14.69798	1350428	0	79.04	2.856209e-313	127.5	96.5	5.1	105.99917	24.792	1
0	2011	14.30011	1396767	0	93.72	3.129825e-313	135.6	96.3	5.1	87.80218	24.792	0
0	2012	14.11543	1478859	0	95.30	3.175953e-313	142.5	96.2	4.6	108.05800	61.250	1
0	2013	14.00908	1315869	0	94.86	2.645133e-313	146.6	96.6	4.3	168.64710	61.250	1
1	2014	13.55841	1268712	0	89.09	2.490221e-313	149.5	99.2	4.0	175.91502	61.263	0

In [5]:
```
# 要約統計量を求める。
raw_data %>%
  summary
```

```
       id              time            Y1               Y2         
 Min.   :0.0000   Min.   :1986   Min.   :11.37   Min.   :1111019  
 1st Qu.:0.0000   1st Qu.:1993   1st Qu.:13.86   1st Qu.:1315869  
 Median :0.0000   Median :2000   Median :14.50   Median :1385835  
 Mean   :0.1379   Mean   :2000   Mean   :14.44   Mean   :1352237  
 3rd Qu.:0.0000   3rd Qu.:2007   3rd Qu.:15.46   3rd Qu.:1422453  
 Max.   :1.0000   Max.   :2014   Max.   :15.74   Max.   :1478859  
       Y3               Y4              Y5                   Y6        
 Min.   :0.0000   Min.   :15.90   Min.   :1.212e-313   Min.   : 36.20  
 1st Qu.:0.0000   1st Qu.:22.40   1st Qu.:2.052e-313   1st Qu.: 41.90  
 Median :0.0000   Median :31.80   Median :2.303e-313   Median : 69.50  
 Mean   :0.2069   Mean   :44.78   Mean   :2.288e-313   Mean   : 77.77  
 3rd Qu.:0.0000   3rd Qu.:71.49   3rd Qu.:2.531e-313   3rd Qu.:102.00  
 Max.   :1.0000   Max.   :95.30   Max.   :3.176e-313   Max.   :149.50  
       Y7               Y8              Y9              Y10       
 Min.   : 85.90   Min.   :2.100   Min.   : 87.8   Min.   :24.79  
 1st Qu.: 96.20   1st Qu.:2.800   1st Qu.:109.8   1st Qu.:47.60  
 Median : 97.20   Median :4.000   Median :168.6   Median :49.38  
 Mean   : 95.83   Mean   :3.731   Mean   :176.3   Mean   :50.20  
 3rd Qu.: 97.70   3rd Qu.:4.700   3rd Qu.:201.9   3rd Qu.:58.59  
 Max.   :100.10   Max.   :5.400   Max.   :439.7   Max.   :61.67  
      Y11        
 Min.   :0.0000  
 1st Qu.:0.0000  
 Median :0.0000  
 Mean   :0.2759  
 3rd Qu.:1.0000  
 Max.   :1.0000  
```

誤差項調整

- 対数差分系列(一次のテイラー展開近似によって変化率に近似するとともに、定常状態として扱う為)
- プロビット写像(Y3: 原子力事故・異常事象(有無)及びY11: 気候変動対策に関する合意(有無))

In [6]:

```
adjusted <- bind_cols(
    raw_data$id[-1]
    , time = raw_data$time[-1]
    , Y1   = diff.log(raw_data$Y1)
    , Y2   = diff.log(raw_data$Y2)
    , Y3   = probit(raw_data$Y3) %>% diff.log
    , Y4   = diff.log(raw_data$Y4)
    , Y5   = diff.log(raw_data$Y5)
    , Y6   = diff.log(raw_data$Y6)
    , Y7   = diff.log(raw_data$Y7)
    , Y8   = diff.log(raw_data$Y8)
    , Y9   = diff.log(raw_data$Y9)
    , Y10  = diff.log(raw_data$Y10)
    , Y11  = probit(raw_data$Y11) %>% diff.log
) %>%
  as.data.frame %>%
  apply(2, as.numeric)
#列名を戻す。
colnames(adjusted) <- colnames(raw_data)
#目視確認
adjusted
```

```
New names:
* `` -> ...1
```

A matrix: 28 × 13 of type dbl

id	time	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11
0	1987	0.046607215	-0.0002075447	0.0	0.14329221	0.1707077926	-0.011862535	0.000000000	0.07410797	0.142432217	0.0000000000	0.0
0	1988	0.054685886	0.0659405832	0.0	-0.27232247	0.1875249212	-0.036456042	0.006960585	0.00000000	0.328497543	0.0000000000	0.0
0	1989	0.034524371	0.0250528768	0.0	0.19834206	0.0005498574	-0.042990185	0.022858138	-0.11332869	0.232060612	0.0000000000	0.0
0	1990	0.038998803	0.0696837388	0.0	0.21128783	0.0213535400	-0.050341755	0.030052345	-0.08338161	-0.519724354	-0.0870144800	0.0
0	1991	0.014394272	0.0108689107	-0.5	-0.15698568	0.1077701561	-0.016438726	0.033426293	-0.09097178	-0.070368106	0.0000000000	0.0
0	1992	0.008714722	0.0088388117	0.5	-0.03704127	0.0555237206	0.019152432	0.015781495	0.00000000	-0.321780945	-0.2076436613	-0.5
0	1993	0.010772766	0.0018240989	0.0	-0.15539469	0.1027744168	0.078164773	0.013478690	0.04652002	0.015192965	0.0000000000	0.5
0	1994	0.034959424	0.0388164337	0.0	-0.02806837	0.0898898827	0.029631798	0.006160184	0.12783337	0.118167806	0.0000000000	-0.5
0	1995	0.031159255	0.0255087629	-0.5	-0.01487016	0.0913039761	0.059049029	-0.001024066	0.14842001	0.008353503	0.0000000000	0.5
0	1996	0.015857401	0.0017371782	0.5	0.19217123	-0.1259988187	0.060084811	0.001024066	0.09844007	-0.026863202	0.0868586003	0.0
0	1997	0.007429008	-0.0068456259	0.0	-0.01512484	-0.0896434279	0.044357853	0.018256085	0.06062462	-0.256382442	0.0000000000	-0.5
0	1998	-0.013351743	-0.0308981841	0.0	-0.33871590	-0.0915824352	0.147635999	0.006012042	0.00000000	-0.103444766	0.0000000000	0.5
0	1999	0.024478952	0.0199589422	-0.5	0.34363431	0.1051333650	0.123904093	-0.003001503	0.18721154	0.316258978	0.0000000000	0.0
0	2000	0.010736322	0.0051230969	0.5	0.45901574	0.0628945041	0.090286847	-0.007038742	0.13657554	-0.310307365	0.0195966413	0.0
0	2001	-0.012860357	-0.0130577529	-0.5	-0.10950287	-0.1242445153	0.084129531	-0.007088637	0.00000000	-0.261116371	0.0000000000	0.0
0	2002	0.014477595	0.0245535532	0.5	0.03522143	-0.0377330966	0.078820960	-0.009188426	0.06187540	-0.196926135	0.0000000000	0.0
1	2003	-0.009538389	0.0039633957	0.0	0.09713002	0.0843494517	0.075329719	-0.003081667	0.07696104	0.221828315	0.0170148206	0.0
0	2004	0.013203009	-0.0004923290	-0.5	0.20097118	0.0890274800	0.082655722	0.000000000	-0.01869213	0.073310989	0.0000000000	0.0
0	2005	-0.004301644	0.0087231997	0.5	0.31611580	-0.0094022430	0.044905504	-0.002059733	-0.12014431	0.341250985	0.2223047186	-0.5
0	2006	0.002755722	-0.0097750164	0.0	0.16065287	-0.0484778413	0.002989539	0.002059733	-0.06595797	0.063789851	0.0000000000	0.5
1	2007	-0.017173256	0.0245626200	-0.5	0.04150997	-0.0002502452	0.014815086	0.000000000	-0.07061757	-0.118048806	0.0000000000	0.0
0	2008	-0.072976716	-0.0535457027	0.5	0.23562571	0.1064360454	0.049723435	0.014300550	-0.05001042	-0.561164644	0.0000000000	-0.5
0	2009	-0.018964102	-0.0709880749	0.0	-0.38749772	0.0376846080	0.118611879	-0.014300550	0.02531781	0.188591810	-0.9112279213	0.5
1	2010	0.042285657	0.0455904399	0.0	0.21075852	0.0715069360	0.054808236	-0.007227703	0.24294618	-0.023341656	0.0000000000	-0.5
0	2011	-0.027443021	0.0337389524	0.0	0.17035756	0.0914819847	0.061593011	-0.002074690	0.00000000	-0.188344936	0.0000000000	0.5
0	2012	-0.012998483	0.0571102968	0.0	0.01671820	0.0146305688	0.049632624	-0.001038961	-0.10318424	0.207581822	0.9044428289	-0.5
0	2013	-0.007562957	-0.1167737613	0.0	-0.00462769	-0.1828865067	0.028365790	0.004149384	-0.06744128	0.445140215	0.0000000000	0.0
1	2014	-0.032698240	-0.0364946245	0.0	-0.06275503	-0.0603497264	0.019588603	0.026559273	-0.07232066	0.042192664	0.0002122224	0.5

多重共線性の実証分析

In [7]:

```r
#確率変数のみのデータフレーム
relation <- adjusted[, !(colnames(adjusted) %in% c("id", "time"))] %>%
  apply(2, as.numeric) %>%
  as.data.frame
#目視確認
relation
```

A data.frame: 28 × 11

Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11
<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
0.046607215	-0.0002075447	0.0	0.14329221	0.1707077926	-0.011862535	0.000000000	0.07410797	0.142432217	0.0000000000	0.0
0.054685886	0.0659405832	0.0	-0.27232247	0.1875249212	-0.036456042	0.006960585	0.00000000	0.328497543	0.0000000000	0.0
0.034524371	0.0250528768	0.0	0.19834206	0.0005498574	-0.042990185	0.022858138	-0.11332869	0.232060612	0.0000000000	0.0
0.038998803	0.0696837388	0.0	0.21128783	0.0213535400	-0.050341755	0.030052345	-0.08338161	-0.519724354	-0.0870144800	0.0
0.014394272	0.0108689107	-0.5	-0.15698568	0.1077701561	-0.016438726	0.033426293	-0.09097178	-0.070368106	0.0000000000	0.0
0.008714722	0.0088388117	0.5	-0.03704127	0.0555237206	0.019152432	0.015781495	0.00000000	-0.321780945	-0.2076436613	-0.5
0.010772766	0.0018240989	0.0	-0.15539469	0.1027744168	0.078164773	0.013478690	0.04652002	0.015192965	0.0000000000	0.5
0.034959424	0.0388164337	0.0	-0.02806837	0.0898898827	0.029631798	0.006160184	0.12783337	0.118167806	0.0000000000	-0.5
0.031159255	0.0255087629	-0.5	-0.01487016	0.0913039761	0.059049029	-0.001024066	0.14842001	0.008353503	0.0000000000	0.5
0.015857401	0.0017371782	0.5	0.19217123	-0.1259988187	0.060084811	0.001024066	0.09844007	-0.026863202	0.0868586003	0.0
0.007429008	-0.0068456259	0.0	-0.01512484	-0.0896434279	0.044357853	0.018256085	0.06062462	-0.256382442	0.0000000000	-0.5
-0.013351743	-0.0308981841	0.0	-0.33871590	-0.0915824352	0.147635999	0.006012042	0.00000000	-0.103444766	0.0000000000	0.5
0.024478952	0.0199589422	-0.5	0.34363431	0.1051333650	0.123904093	-0.003001503	0.18721154	0.316258978	0.0000000000	0.0
0.010736322	0.0051230969	0.5	0.45901574	0.0628945041	0.090286847	-0.007038742	0.13657554	-0.310307365	0.0195966413	0.0
-0.012860357	-0.0130577529	-0.5	-0.10950287	-0.1242445153	0.084129531	-0.007088637	0.00000000	-0.261116371	0.0000000000	0.0
0.014477595	0.0245535532	0.5	0.03522143	-0.0377330966	0.078820960	-0.009188426	0.06187540	-0.196926135	0.0000000000	0.0
-0.009538389	0.0039633957	0.0	0.09713002	0.0843494517	0.075329719	-0.003081667	0.07696104	0.221828315	0.0170148206	0.0
0.013203009	-0.0004923290	-0.5	0.20097118	0.0890274800	0.082655722	0.000000000	-0.01869213	0.073310989	0.0000000000	0.0
-0.004301644	0.0087231997	0.5	0.31611580	-0.0094022430	0.044905504	-0.002059733	-0.12014431	0.341250985	0.2223047186	-0.5
0.002755722	-0.0097750164	0.0	0.16065287	-0.0484778413	0.002989539	0.002059733	-0.06595797	0.063789851	0.0000000000	0.5
-0.017173256	0.0245626200	-0.5	0.04150997	-0.0002502452	0.014815086	0.000000000	-0.07061757	-0.118048806	0.0000000000	0.0
-0.072976716	-0.0535457027	0.5	0.23562571	0.1064360454	0.049723435	0.014300550	-0.05001042	-0.561164644	0.0000000000	-0.5
-0.018964102	-0.0709880749	0.0	-0.38749772	0.0376846080	0.118611879	-0.014300550	0.02531781	0.188591810	-0.9112279213	0.5
0.042285657	0.0455904399	0.0	0.21075852	0.0715069360	0.054808236	-0.007227703	0.24294618	-0.023341656	0.0000000000	-0.5
-0.027443021	0.0337389524	0.0	0.17035756	0.0914819847	0.061593011	-0.002074690	0.00000000	-0.188344936	0.0000000000	0.5
-0.012998483	0.0571102968	0.0	0.01671820	0.0146305688	0.049632624	-0.001038961	-0.10318424	0.207581822	0.9044428289	-0.5
-0.007562957	-0.1167737613	0.0	-0.00462769	-0.1828865067	0.028365790	0.004149384	-0.06744128	0.445140215	0.0000000000	0.0
-0.032698240	-0.0364946245	0.0	-0.06275503	-0.0603497264	0.019588603	0.026559273	-0.07232066	0.042192664	0.0002122224	0.5

無相関検定

- 相関係数に統計的有意性を検出すれば、多重共線性がある。

In [8]:
```r
#Y1～11
cor.test(relation$Y1, relation$Y2,  method = "pearson")
cor.test(relation$Y1, relation$Y3,  method = "pearson")
cor.test(relation$Y1, relation$Y4,  method = "pearson")
cor.test(relation$Y1, relation$Y5,  method = "pearson")
cor.test(relation$Y1, relation$Y6,  method = "pearson")
cor.test(relation$Y1, relation$Y7,  method = "pearson")
cor.test(relation$Y1, relation$Y8,  method = "pearson")
cor.test(relation$Y1, relation$Y9,  method = "pearson")
cor.test(relation$Y1, relation$Y10, method = "pearson")
cor.test(relation$Y1, relation$Y11, method = "pearson")
#Y2～11
cor.test(relation$Y2, relation$Y3,  method = "pearson")
cor.test(relation$Y2, relation$Y4,  method = "pearson")
cor.test(relation$Y2, relation$Y5,  method = "pearson")
cor.test(relation$Y2, relation$Y6,  method = "pearson")
cor.test(relation$Y2, relation$Y7,  method = "pearson")
cor.test(relation$Y2, relation$Y8,  method = "pearson")
cor.test(relation$Y2, relation$Y9,  method = "pearson")
cor.test(relation$Y2, relation$Y10, method = "pearson")
cor.test(relation$Y2, relation$Y11, method = "pearson")
#Y3～11
cor.test(relation$Y3, relation$Y4,  method = "pearson")
cor.test(relation$Y3, relation$Y5,  method = "pearson")
cor.test(relation$Y3, relation$Y6,  method = "pearson")
cor.test(relation$Y3, relation$Y7,  method = "pearson")
cor.test(relation$Y3, relation$Y8,  method = "pearson")
cor.test(relation$Y3, relation$Y9,  method = "pearson")
cor.test(relation$Y3, relation$Y10, method = "pearson")
cor.test(relation$Y3, relation$Y11, method = "pearson")
#Y4～11
cor.test(relation$Y4, relation$Y5,  method = "pearson")
cor.test(relation$Y4, relation$Y6,  method = "pearson")
cor.test(relation$Y4, relation$Y7,  method = "pearson")
cor.test(relation$Y4, relation$Y8,  method = "pearson")
cor.test(relation$Y4, relation$Y9,  method = "pearson")
cor.test(relation$Y4, relation$Y10, method = "pearson")
cor.test(relation$Y4, relation$Y11, method = "pearson")
#Y5～11
cor.test(relation$Y5, relation$Y6,  method = "pearson")
cor.test(relation$Y5, relation$Y7,  method = "pearson")
cor.test(relation$Y5, relation$Y8,  method = "pearson")
cor.test(relation$Y5, relation$Y9,  method = "pearson")
cor.test(relation$Y5, relation$Y10, method = "pearson")
cor.test(relation$Y5, relation$Y11, method = "pearson")
#Y6～11
cor.test(relation$Y6, relation$Y7,  method = "pearson")
cor.test(relation$Y6, relation$Y8,  method = "pearson")
cor.test(relation$Y6, relation$Y9,  method = "pearson")
cor.test(relation$Y6, relation$Y10, method = "pearson")
cor.test(relation$Y6, relation$Y11, method = "pearson")
#Y7～11
cor.test(relation$Y7, relation$Y8,  method = "pearson")
cor.test(relation$Y7, relation$Y9,  method = "pearson")
cor.test(relation$Y7, relation$Y10, method = "pearson")
cor.test(relation$Y7, relation$Y11, method = "pearson")
#Y8～11
cor.test(relation$Y8, relation$Y9,  method = "pearson")
cor.test(relation$Y8, relation$Y10, method = "pearson")
cor.test(relation$Y8, relation$Y11, method = "pearson")
#Y9～11
cor.test(relation$Y9, relation$Y10, method = "pearson")
cor.test(relation$Y9, relation$Y11, method = "pearson")
#Y10～11
cor.test(relation$Y10,relation$Y11, method = "pearson")
```

```
	Pearson's product-moment correlation

data:  relation$Y1 and relation$Y2
t = 3.5192, df = 26, p-value = 0.001615
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 0.2473685 0.7765393
sample estimates:
      cor 
0.5680239 


	Pearson's product-moment correlation

data:  relation$Y1 and relation$Y3
t = -0.8296, df = 26, p-value = 0.4143
alternative hypothesis: true correlation is not equal to 0
95 percent confidence interval:
 -0.5034983  0.2260323
```

多変量時系列分析

- 単位根検定(ADF検定)
- 共和分検定
- 偏グレンジャー因果性検定と非直交化インパルス応答関数
- パネルVARモデルによる動的直接相関係数の導出
- 幾何ブラウン運動と確率偏微分方程式
- LSTM(Long Short Term Memory)

単位根検定(ADF検定)

In [9]:
```
relation %>%
  apply(2, ADF)
```

```
$Y1

###############################################
# Augmented Dickey-Fuller Test Unit Root Test #
###############################################

Test regression drift


Call:
lm(formula = z.diff ~ z.lag.1 + 1 + z.diff.lag)

Residuals:
     Min       1Q   Median       3Q      Max
-0.06802 -0.01276  0.00237  0.01493  0.05123

Coefficients:
              Estimate Std. Error t value Pr(>|t|)
(Intercept)  0.0004843  0.0052101   0.093  0.92674
```

共和分検定

In [10]:
```
#Y1～11
coint.test(relation$Y1, relation$Y2,  nlag = 1) %>% summary
coint.test(relation$Y1, relation$Y3,  nlag = 1) %>% summary
coint.test(relation$Y1, relation$Y4,  nlag = 1) %>% summary
coint.test(relation$Y1, relation$Y5,  nlag = 1) %>% summary
coint.test(relation$Y1, relation$Y6,  nlag = 1) %>% summary
coint.test(relation$Y1, relation$Y7,  nlag = 1) %>% summary
coint.test(relation$Y1, relation$Y8,  nlag = 1) %>% summary
coint.test(relation$Y1, relation$Y9,  nlag = 1) %>% summary
coint.test(relation$Y1, relation$Y10, nlag = 1) %>% summary
coint.test(relation$Y1, relation$Y11, nlag = 1) %>% summary
#Y2～11
coint.test(relation$Y2, relation$Y3,  nlag = 1) %>% summary
coint.test(relation$Y2, relation$Y4,  nlag = 1) %>% summary
coint.test(relation$Y2, relation$Y6,  nlag = 1) %>% summary
coint.test(relation$Y2, relation$Y7,  nlag = 1) %>% summary
coint.test(relation$Y2, relation$Y8,  nlag = 1) %>% summary
coint.test(relation$Y2, relation$Y9,  nlag = 1) %>% summary
coint.test(relation$Y2, relation$Y10, nlag = 1) %>% summary
coint.test(relation$Y2, relation$Y11, nlag = 1) %>% summary
#Y3～11
coint.test(relation$Y3, relation$Y4,  nlag = 1) %>% summary
coint.test(relation$Y3, relation$Y5,  nlag = 1) %>% summary
coint.test(relation$Y3, relation$Y6,  nlag = 1) %>% summary
coint.test(relation$Y3, relation$Y7,  nlag = 1) %>% summary
coint.test(relation$Y3, relation$Y8,  nlag = 1) %>% summary
coint.test(relation$Y3, relation$Y9,  nlag = 1) %>% summary
coint.test(relation$Y3, relation$Y10, nlag = 1) %>% summary
coint.test(relation$Y3, relation$Y11, nlag = 1) %>% summary
#Y4～11
coint.test(relation$Y4, relation$Y5,  nlag = 1) %>% summary
coint.test(relation$Y4, relation$Y6,  nlag = 1) %>% summary
coint.test(relation$Y4, relation$Y7,  nlag = 1) %>% summary
coint.test(relation$Y4, relation$Y8,  nlag = 1) %>% summary
coint.test(relation$Y4, relation$Y9,  nlag = 1) %>% summary
coint.test(relation$Y4, relation$Y10, nlag = 1) %>% summary
coint.test(relation$Y4, relation$Y11, nlag = 1) %>% summary
#Y5～11
coint.test(relation$Y5, relation$Y6,  nlag = 1) %>% summary
coint.test(relation$Y5, relation$Y7,  nlag = 1) %>% summary
coint.test(relation$Y5, relation$Y8,  nlag = 1) %>% summary
coint.test(relation$Y5, relation$Y9,  nlag = 1) %>% summary
coint.test(relation$Y5, relation$Y10, nlag = 1) %>% summary
coint.test(relation$Y5, relation$Y11, nlag = 1) %>% summary
#Y6～11
coint.test(relation$Y6, relation$Y7,  nlag = 1) %>% summary
coint.test(relation$Y6, relation$Y8,  nlag = 1) %>% summary
coint.test(relation$Y6, relation$Y9,  nlag = 1) %>% summary
coint.test(relation$Y6, relation$Y10, nlag = 1) %>% summary
coint.test(relation$Y6, relation$Y11, nlag = 1) %>% summary
#Y7～11
coint.test(relation$Y7, relation$Y8,  nlag = 1) %>% summary
coint.test(relation$Y7, relation$Y9,  nlag = 1) %>% summary
coint.test(relation$Y7, relation$Y10, nlag = 1) %>% summary
coint.test(relation$Y7, relation$Y11, nlag = 1) %>% summary
#Y8～11
coint.test(relation$Y8, relation$Y9,  nlag = 1) %>% summary
coint.test(relation$Y8, relation$Y10, nlag = 1) %>% summary
coint.test(relation$Y8, relation$Y11, nlag = 1) %>% summary
#Y9～11
coint.test(relation$Y9, relation$Y10, nlag = 1) %>% summary
coint.test(relation$Y9, relation$Y11, nlag = 1) %>% summary
#Y10～11
coint.test(relation$Y10, relation$Y11, nlag = 1) %>% summary
```

```
Response: relation$Y1
Input: relation$Y2
Number of inputs: 1
Model: y ~ X + 1
-------------------------------
Engle-Granger Cointegration Test
alternative: cointegrated

Type 1: no trend
    lag      EG p.value
   1.00   -4.55    0.01
-----
 Type 2: linear trend
    lag      EG p.value
   1.00   -1.44    0.10
-----
 Type 3: quadratic trend
    lag      EG p.value
  1.000   0.826   0.100
```

偏グレンジャー因果性検定と非直交化インパルス応答関数

In [11]:
```
#Y1～11
ts(relation$Y1, relation$Y2)
ts(relation$Y1, relation$Y3)
ts(relation$Y1, relation$Y4)
ts(relation$Y1, relation$Y5)
ts(relation$Y1, relation$Y6)
ts(relation$Y1, relation$Y7)
ts(relation$Y1, relation$Y8)
ts(relation$Y1, relation$Y9)
ts(relation$Y1, relation$Y10)
ts(relation$Y1, relation$Y11)
#Y2～11
ts(relation$Y2, relation$Y3)
ts(relation$Y2, relation$Y4)
ts(relation$Y2, relation$Y5)
ts(relation$Y2, relation$Y6)
ts(relation$Y2, relation$Y7)
ts(relation$Y2, relation$Y8)
ts(relation$Y2, relation$Y9)
ts(relation$Y2, relation$Y10)
ts(relation$Y2, relation$Y11)
#Y3～11
ts(relation$Y3, relation$Y4)
ts(relation$Y3, relation$Y5)
ts(relation$Y3, relation$Y6)
ts(relation$Y3, relation$Y7)
ts(relation$Y3, relation$Y8)
ts(relation$Y3, relation$Y9)
ts(relation$Y3, relation$Y10)
ts(relation$Y3, relation$Y11)
#Y4～11
ts(relation$Y4, relation$Y5)
ts(relation$Y4, relation$Y6)
ts(relation$Y4, relation$Y7)
ts(relation$Y4, relation$Y8)
ts(relation$Y4, relation$Y9)
ts(relation$Y4, relation$Y10)
ts(relation$Y4, relation$Y11)
#Y5～11
ts(relation$Y5, relation$Y6)
ts(relation$Y5, relation$Y7)
ts(relation$Y5, relation$Y8)
ts(relation$Y5, relation$Y9)
ts(relation$Y5, relation$Y10)
ts(relation$Y5, relation$Y11)
#Y6～11
ts(relation$Y6, relation$Y7)
ts(relation$Y6, relation$Y8)
ts(relation$Y6, relation$Y9)
ts(relation$Y6, relation$Y10)
ts(relation$Y6, relation$Y11)
#Y7～11
ts(relation$Y7, relation$Y8)
ts(relation$Y7, relation$Y9)
ts(relation$Y7, relation$Y10)
ts(relation$Y7, relation$Y11)
#Y8～11
ts(relation$Y8, relation$Y9)
ts(relation$Y8, relation$Y10)
ts(relation$Y8, relation$Y11)
#Y9～11
ts(relation$Y9, relation$Y10)
ts(relation$Y9, relation$Y11)
#Y10～11
ts(relation$Y10, relation$Y11)
```

```
[[1]]
[[1]][[1]]
[[1]][[1]]$Granger

	Granger causality H0: y1 do not Granger-cause y2

data:  VAR object model
F-Test = 2.6256, df1 = 2, df2 = 40, p-value = 0.08484


[[1]][[1]]$Instant

	H0: No instantaneous causality between: y1 and y2

data:  VAR object model
Chi-squared = 7.1644, df = 1, p-value = 0.007436



[[1]][[2]]
```

パネルVARモデルによる動的直接相関係数の導出

1. パネルデータの生成
2. 目視確認
3. 要約統計量を求める。
4. モデル形成
5. 詳細結果の目視確認
6. 動的直接相関係数の抽出
7. パネルVARモデルの標準誤差の抽出

In [12]:
```r
#パネルデータの生成
index <- adjusted[, 1:2] %>% apply(2, as.character) %>% as.data.frame
panel <- bind_cols(index, relation) %>% pdata.frame(index = c("id", "time"))
#目視確認
panel
```

A pdata.frame: 28 × 13

	id	time	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11
	<fct>	<fct>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
0-1987	0	1987	0.046607215	-0.0002075447	0.0	0.14329221	0.1707077926	-0.011862535	0.000000000	0.07410797	0.142432217	0.0000000000	0.0
0-1988	0	1988	0.054685886	0.0659405832	0.0	-0.27232247	0.1875249212	-0.036456042	0.006960585	0.00000000	0.328497543	0.0000000000	0.0
0-1989	0	1989	0.034524371	0.0250528768	0.0	0.19834206	0.0005498574	-0.042990185	0.022858138	-0.11332869	0.232060612	0.0000000000	0.0
0-1990	0	1990	0.038998803	0.0696837388	0.0	0.21128783	0.0213535400	-0.050341755	0.030052345	-0.08338161	-0.519724354	-0.0870144800	0.0
0-1991	0	1991	0.014394272	0.0108689107	-0.5	-0.15698568	0.1077701561	-0.016438726	0.033426293	-0.09097178	-0.070368106	0.0000000000	0.0
0-1992	0	1992	0.008714722	0.0088388117	0.5	-0.03704127	0.0555237206	0.019152432	0.015781495	0.00000000	-0.321780945	-0.2076436613	-0.5
0-1993	0	1993	0.010772766	0.0018240989	0.0	-0.15539469	0.1027744168	0.078164773	0.013478690	0.04652002	0.015192965	0.0000000000	0.5
0-1994	0	1994	0.034959424	0.0388164337	0.0	-0.02806837	0.0898898827	0.029631798	0.006160184	0.12783337	0.118167806	0.0000000000	-0.5
0-1995	0	1995	0.031159255	0.0255087629	-0.5	-0.01487016	0.0913039761	0.059049029	-0.001024066	0.14842001	0.008353503	0.0000000000	0.5
0-1996	0	1996	0.015857401	0.0017371782	0.5	0.19217123	-0.1259988187	0.060084811	0.001024066	0.09844007	-0.026863202	0.0868586003	0.0
0-1997	0	1997	0.007429008	-0.0068456259	0.0	-0.01512484	-0.0896434279	0.044357853	0.018256085	0.06062462	-0.256382442	0.0000000000	-0.5
0-1998	0	1998	-0.013351743	-0.0308981841	0.0	-0.33871590	-0.0915824352	0.147635999	0.006012042	0.00000000	-0.103444766	0.0000000000	0.5
0-1999	0	1999	0.024478952	0.0199589422	-0.5	0.34363431	0.1051333650	0.123904093	-0.003001503	0.18721154	0.316258978	0.0000000000	0.0
0-2000	0	2000	0.010736322	0.0051230969	0.5	0.45901574	0.0628945041	0.090286847	-0.007038742	0.13657554	-0.310307365	0.0195966413	0.0
0-2001	0	2001	-0.012860357	-0.0130577529	-0.5	-0.10950287	-0.1242445153	0.084129531	-0.007088637	0.00000000	-0.261116371	0.0000000000	0.0
0-2002	0	2002	0.014477595	0.0245535532	0.5	0.03522143	-0.0377330966	0.078820960	-0.009188426	0.06187540	-0.196926135	0.0000000000	0.0
0-2004	0	2004	0.013203009	-0.0004923290	-0.5	0.20097118	0.0890274800	0.082655722	0.000000000	-0.01869213	0.073310989	0.0000000000	0.0
0-2005	0	2005	-0.004301644	0.0087231997	0.5	0.31611580	-0.0094022430	0.044905504	-0.002059733	-0.12014431	0.341250985	0.2223047186	-0.5
0-2006	0	2006	0.002755722	-0.0097750164	0.0	0.16065287	-0.0484778413	0.002989539	0.002059733	-0.06595797	0.063789851	0.0000000000	0.5
0-2008	0	2008	-0.072976716	-0.0535457027	0.5	0.23562571	0.1064360454	0.049723435	0.014300550	-0.05001042	-0.561164644	0.0000000000	-0.5
0-2009	0	2009	-0.018964102	-0.0709880749	0.0	-0.38749772	0.0376846080	0.118611879	-0.014300550	0.02531781	0.188591810	-0.9112279213	0.5
0-2011	0	2011	-0.027443021	0.0337389524	0.0	0.17035756	0.0914819847	0.061593011	-0.002074690	0.00000000	-0.188344936	0.0000000000	0.5
0-2012	0	2012	-0.012998483	0.0571102968	0.0	0.01671820	0.0146305688	0.049632624	-0.001038961	-0.10318424	0.207581822	0.9044428289	-0.5
0-2013	0	2013	-0.007562957	-0.1167737613	0.0	-0.00462769	-0.1828865067	0.028365790	0.004149384	-0.06744128	0.445140215	0.0000000000	0.0
1-2003	1	2003	-0.009538389	0.0039633957	0.0	0.09713002	0.0843494517	0.075329719	-0.003081667	0.07696104	0.221828315	0.0170148206	0.0
1-2007	1	2007	-0.017173256	0.0245626200	-0.5	0.04150997	-0.0002502452	0.014815086	0.000000000	-0.07061757	-0.118048806	0.0000000000	0.0
1-2010	1	2010	0.042285657	0.0455904399	0.0	0.21075852	0.0715069360	0.054808236	-0.007227703	0.24294618	-0.023341656	0.0000000000	-0.5
1-2014	1	2014	-0.032698240	-0.0364946245	0.0	-0.06275503	-0.0603497264	0.019588603	0.026559273	-0.07232066	0.042192664	0.0002122224	0.5

In [13]:
```r
#要約統計量を求める。
panel %>%
  summary
```

```
 id          time           Y1                  Y2                  Y3
 0:24   1987    : 1   Min.    :-0.072977   Min.    :-0.116774   Min.    :-0.5
 1: 4   1988    : 1   1st Qu.:-0.012895   1st Qu.:-0.007578   1st Qu.: 0.0
        1989    : 1   Median : 0.009726   Median : 0.006923   Median : 0.0
        1990    : 1   Mean   : 0.006292   Mean   : 0.004733   Mean   : 0.0
        1991    : 1   3rd Qu.: 0.026149   3rd Qu.: 0.025167   3rd Qu.: 0.0
        1992    : 1   Max.   : 0.054686   Max.   : 0.069684   Max.   : 0.5
        (Other):22
       Y4                 Y5                 Y6                 Y7
 Min.   :-0.38750   Min.   :-0.18289   Min.   :-0.05034   Min.   :-0.014301
 1st Qu.:-0.04347   1st Qu.:-0.04042   1st Qu.: 0.01807   1st Qu.:-0.002306
 Median : 0.03837   Median : 0.04660   Median : 0.04968   Median : 0.000512
 Mean   : 0.05178   Mean   : 0.02571   Mean   : 0.04501   Mean   : 0.005141
 3rd Qu.: 0.19900   3rd Qu.: 0.09135   3rd Qu.: 0.07833   3rd Qu.: 0.013684
 Max.   : 0.45902   Max.   : 0.18752   Max.   : 0.14764   Max.   : 0.033426

       Y8                 Y9                  Y10                 Y11
 Min.   :-0.12014   Min.   :-0.561165   Min.   :-0.911228   Min.   :-0.500
 1st Qu.:-0.06824   1st Qu.:-0.190490   1st Qu.: 0.000000   1st Qu.:-0.125
 Median : 0.00000   Median : 0.011773   Median : 0.000000   Median : 0.000
 Mean   : 0.01539   Mean   :-0.007613   Mean   : 0.001591   Mean   : 0.000
 3rd Qu.: 0.07482   3rd Qu.: 0.193339   3rd Qu.: 0.000000   3rd Qu.: 0.125
 Max.   : 0.24295   Max.   : 0.445140   Max.   : 0.904443   Max.   : 0.500
```

In [14]:
```r
#モデルの形成
model <- pvargmm(dependent_vars = c("Y1", "Y2", "Y3", "Y4", "Y5", "Y6", "Y7", "Y8", "Y9", "Y10", "Y11"),
                 lags = 1,
                 transformation = c("fod"),
                 data = panel,
                 panel_identifier =  c("id", "time"),
                 steps = c("twostep"),
                 system_instruments = F,
                 max_instr_dependent_vars = 2,
                 min_instr_dependent_vars = 1L
)
```

```
Warning message in pvargmm(dependent_vars = c("Y1", "Y2", "Y3", "Y4", "Y5", "Y6", :
"The matrix Lambda is singular, therefore the general inverse is used"

 One-step estimation: Matrix inversion


Warning message in pvargmm(dependent_vars = c("Y1", "Y2", "Y3", "Y4", "Y5", "Y6", :
"The matrix D_e is singular, therefore the general inverse is used"
Warning message in sqrt(diag(var_first_step)):
" 計算結果が NaN になりました "

Windmeijer - Sigmund robust se: [==========================] Iteration 2 of 2
```

In [15]:
```r
#詳細結果の目視確認
model %>%
  summary
```

```
---------------------------------------------------
Dynamic Panel VAR estimation, two-step GMM
---------------------------------------------------
Transformation: Forward orthogonal deviations
Group variable: id
Time variable: time
Number of observations = 16
Number of groups = 2
Obs per group: min = 0
               avg = 8
               max = 16
Number of instruments = 6171
```

	Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11
lag1_Y1	-0.0028	-0.0062	0.2220	-0.0480	-0.0713	0.0020	-0.0032	0.0356	-0.2040	0.0030	0.0694
	(0.0029)	(0.0064)	(0.2297)	(0.0497)	(0.0737)	(0.0021)	(0.0033)	(0.0368)	(0.2110)	(0.0031)	(0.0718)
lag1_Y2	-0.0050	0.0275	0.0665	-0.0711	0.0470	0.0084	0.0002	0.0002	0.0185	0.3901	-0.0490
	(0.0052)	(0.0285)	(0.0688)	(0.0736)	(0.0486)	(0.0086)	(0.0003)	(0.0002)	(0.0191)	(0.4036)	(0.0506)
lag1_Y3	-0.1693	-0.0996	1.1327	0.3829	-0.9092	0.0764	0.0159	-0.6283	-0.1379	1.2018	-3.0932
	(0.1752)	(0.1031)	(1.1719)	(0.3962)	(0.9407)	(0.0791)	(0.0164)	(0.6501)	(0.1427)	(1.2434)	(3.2002)
lag1_Y4	-0.1018	-0.2031	0.1416	0.4216	-0.7854	0.0740	-0.0072	-0.3813	-0.7137	-1.1339	-0.3781
	(0.1053)	(0.2101)	(0.1465)	(0.4362)	(0.8126)	(0.0765)	(0.0075)	(0.3945)	(0.7384)	(1.1731)	(0.3911)
lag1_Y5	0.0010	-0.0201	0.2714	0.1218	-0.1988	0.0155	-0.0015	0.0306	-0.2511	-0.1497	0.3809
	(0.0010)	(0.0208)	(0.2808)	(0.1260)	(0.2057)	(0.0160)	(0.0016)	(0.0316)	(0.2598)	(0.1548)	(0.3941)
lag1_Y6	0.0185	0.0151	-0.4520	0.0361	0.1133	-0.0066	-0.0019	0.0210	-0.0355	-0.2796	0.3409
	(0.0191)	(0.0156)	(0.4676)	(0.0373)	(0.1173)	(0.0068)	(0.0019)	(0.0218)	(0.0367)	(0.2893)	(0.3527)
lag1_Y7	-0.0003	0.0018	0.0511	-0.0136	0.0153	-0.0011	0.0011	-0.0023	0.0392	0.0517	-0.0450
	(0.0003)	(0.0019)	(0.0528)	(0.0141)	(0.0158)	(0.0011)	(0.0012)	(0.0024)	(0.0405)	(0.0535)	(0.0465)
lag1_Y8	0.0099	-0.0455	0.1571	0.3401	-0.2181	-0.0049	-0.0012	0.0360	-0.8514	-0.9308	0.3010
	(0.0103)	(0.0471)	(0.1626)	(0.3519)	(0.2257)	(0.0051)	(0.0012)	(0.0372)	(0.8809)	(0.9630)	(0.3115)
lag1_Y9	0.0137	-0.0172	0.1555	-1.0944	0.2983	-0.0133	-0.0235	0.2952	1.5217	0.7877	0.7928
	(0.0142)	(0.0178)	(0.1608)	(1.1323)	(0.3086)	(0.0138)	(0.0243)	(0.3054)	(1.5743)	(0.8150)	(0.8203)
lag1_Y10	-0.0772	0.1379	-1.5153	-0.4357	0.3174	0.0684	0.0029	-0.4685	1.6202	2.3678	-1.2263
	(0.0799)	(0.1427)	(1.5677)	(0.4508)	(0.3284)	(0.0708)	(0.0030)	(0.4847)	(1.6762)	(2.4498)	(1.2688)
lag1_Y11	0.0971	0.0105	-0.2774	-0.0540	-0.1086	-0.1045	-0.0170	0.3311	-0.9623	-1.6206	0.6966
	(0.1004)	(0.0108)	(0.2870)	(0.0559)	(0.1124)	(0.1081)	(0.0176)	(0.3425)	(0.9956)	(1.6767)	(0.7207)

```
*** p < 0.001; ** p < 0.01; * p < 0.05

---------------------------------------------------
Instruments for  equation
 Standard

 GMM-type
  Dependent vars: L(1, 2)
  Collapse =  FALSE
---------------------------------------------------

Hansen test of overid. restrictions: chi2(6050) = 0 Prob > chi2 = 1
(Robust, but weakened by many instruments.)
```

In [16]:
```
#動的直接相関係数の抽出
coefficient <- model %>%
  coef %>%
  apply(2, as.numeric) %>%
  as.data.frame
coefficient
```

A data.frame: 11 × 11

fod_lag1_Y1	fod_lag1_Y2	fod_lag1_Y3	fod_lag1_Y4	fod_lag1_Y5	fod_lag1_Y6	fod_lag1_Y7	fod_lag1_Y8	fod_lag1_Y9	fod_lag1_Y10	fod_lag1_Y11
<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
-0.002755249	-0.0050207787	-0.16931255	-0.101768112	0.0009635997	0.018466039	-0.0002774653	0.009914154	0.01369006	-0.077207792	0.09705778
-0.006195090	0.0275329642	-0.09964652	-0.203052304	-0.0201305406	0.015078743	0.0018038768	-0.045506299	-0.01724720	0.137895850	0.01045967
0.222002529	0.0665407711	1.13272639	0.141606922	0.2713863935	-0.451975130	0.0510547863	0.157144539	0.15545010	-1.515287824	-0.27741172
-0.048013232	-0.0711160547	0.38291057	0.421612797	0.1218261696	0.036098516	-0.0135971765	0.340138699	-1.09443628	-0.435713156	-0.05399573
-0.071277637	0.0469653214	-0.90920739	-0.785444930	-0.1987902325	0.113329527	0.0152993784	-0.218143602	0.29830157	0.317430644	-0.10862941
0.002014497	0.0083530692	0.07643506	0.073981297	0.0154727523	-0.006572534	-0.0010711035	-0.004921998	-0.01333021	0.068395469	-0.10447770
-0.003231988	0.0002458802	0.01588686	-0.007247741	-0.0015249092	-0.001877827	0.0011170139	-0.001197610	-0.02346839	0.002867628	-0.01703419
0.035585016	0.0001843510	-0.62833666	-0.381344959	0.0305652783	0.021040742	-0.0023231949	0.035958589	0.29516954	-0.468530403	0.33108238
-0.203964391	0.0184871855	-0.13789203	-0.713690182	-0.2511128046	-0.035476207	0.0391586341	-0.851447218	1.52166575	1.620152172	-0.96231174
0.002957264	0.3900753633	1.20176931	-1.133852030	-0.1496687682	-0.279649802	0.0517230279	-0.930755480	0.78773599	2.367832667	-1.62063087
0.069353903	-0.0489548229	-3.09319628	-0.378062190	0.3809335545	0.340858601	-0.0449922690	0.301033813	0.79282291	-1.226328617	0.69663788

In [17]:
```
#要約統計量を求める。
coefficient %>%
  summary
```

```
  fod_lag1_Y1          fod_lag1_Y2          fod_lag1_Y3          fod_lag1_Y4
 Min.   :-0.2039644   Min.   :-0.071116   Min.   :-3.09320   Min.   :-1.13385
 1st Qu.:-0.0271042   1st Qu.:-0.002418   1st Qu.:-0.39882   1st Qu.:-0.54752
 Median :-0.0027552   Median : 0.008353   Median :-0.09965   Median :-0.20305
 Mean   :-0.0003204   Mean   : 0.039390   Mean   :-0.20253   Mean   :-0.27884
 3rd Qu.: 0.0192711   3rd Qu.: 0.037249   3rd Qu.: 0.22967   3rd Qu.: 0.03337
 Max.   : 0.2220025   Max.   : 0.390075   Max.   : 1.20177   Max.   : 0.42161
  fod_lag1_Y5          fod_lag1_Y6         fod_lag1_Y7
 Min.   :-0.2511128   Min.   :-0.45198   Min.   :-0.044992
 1st Qu.:-0.0848997   1st Qu.:-0.02102   1st Qu.:-0.001697
 Median : 0.0009636   Median : 0.01508   Median : 0.001117
 Mean   : 0.0181746   Mean   :-0.02097   Mean   : 0.008900
 3rd Qu.: 0.0761957   3rd Qu.: 0.02857   3rd Qu.: 0.027229
 Max.   : 0.3809336   Max.   : 0.34086   Max.   : 0.051723
  fod_lag1_Y8         fod_lag1_Y9         fod_lag1_Y10         fod_lag1_Y11
 Min.   :-0.930755   Min.   :-1.09444   Min.   :-1.515288   Min.   :-1.62063
 1st Qu.:-0.131825   1st Qu.:-0.01529   1st Qu.:-0.452122   1st Qu.:-0.19302
 Median :-0.001198   Median : 0.15545   Median : 0.002868   Median :-0.05400
 Mean   :-0.109798   Mean   : 0.24694   Mean   : 0.071955   Mean   :-0.18266
 3rd Qu.: 0.096552   3rd Qu.: 0.54302   3rd Qu.: 0.227663   3rd Qu.: 0.05376
 Max.   : 0.340139   Max.   : 1.52167   Max.   : 2.367833   Max.   : 0.69664
```

In [18]:
```
#モデルの標準誤差
SE <- model %>%
  se %>%
  apply(2, as.numeric) %>%
  as.data.frame
SE
```

A data.frame: 11 × 11

V1	V2	V3	V4	V5	V6	V7	V8	V9	V10	V11
<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
0.002850591	0.0051945161	0.1751714	0.10528966	0.0009969438	0.019105032	0.0002870666	0.010257220	0.01416379	0.079879466	0.10041634
0.006409463	0.0284857061	0.1030947	0.21007866	0.0208271314	0.015600523	0.0018662976	0.047080984	0.01784402	0.142667554	0.01082161
0.229684634	0.0688433269	1.1719229	0.14650704	0.2807773622	0.467615134	0.0528214700	0.162582319	0.16082925	1.567722364	0.28701119
0.049674667	0.0735769322	0.3961607	0.43620215	0.1260418038	0.037347657	0.0140676889	0.351908751	1.13230781	0.450790436	0.05586418
0.073744106	0.0485904945	0.9406693	0.81262422	0.2056691068	0.117251146	0.0158287932	0.225692174	0.30862390	0.328414913	0.11238839
0.002084206	0.0086421162	0.0790800	0.07654132	0.0160081665	0.006799968	0.0011081676	0.005092317	0.01379148	0.070762204	0.10809301
0.003343827	0.0002543886	0.0164366	0.00749854	0.0015776767	0.001942807	0.0011556667	0.001239051	0.02428048	0.002966858	0.01762364
0.036816389	0.0001907302	0.6500794	0.39454090	0.0316229495	0.021768829	0.0024035860	0.037202888	0.30538349	0.484743280	0.34253905
0.211022310	0.0191269102	0.1426636	0.73838649	0.2598022325	0.036703814	0.0405136671	0.880910427	1.57432099	1.676215404	0.99561127
0.003059596	0.4035734076	1.2433549	1.17308749	0.1548478588	0.289326715	0.0535128352	0.962963048	0.81499456	2.449768398	1.67671066
0.071753804	0.0506488401	3.2002323	0.39114453	0.3941152585	0.352653564	0.0465491672	0.311450692	0.82025750	1.268764104	0.72074411

In [19]:
```
#要約統計量を求める。
SE %>%
  summary
```

```
       V1                  V2                  V3                V4
 Min.   :0.002084   Min.   :0.0001907   Min.   :0.01644   Min.   :0.007498
 1st Qu.:0.003202   1st Qu.:0.0069183   1st Qu.:0.12288   1st Qu.:0.125898
 Median :0.036816   Median :0.0284857   Median :0.39616   Median :0.391145
 Mean   :0.062768   Mean   :0.0642843   Mean   :0.73808   Mean   :0.408355
 3rd Qu.:0.072749   3rd Qu.:0.0597461   3rd Qu.:1.05630   3rd Qu.:0.587294
 Max.   :0.229685   Max.   :0.4035734   Max.   :3.20023   Max.   :1.173088
       V5                   V6                  V7                  V8
 Min.   :0.0009969   Min.   :0.001943   Min.   :0.0002871   Min.   :0.001239
 1st Qu.:0.0184176   1st Qu.:0.017353   1st Qu.:0.0015110   1st Qu.:0.023730
 Median :0.1260418   Median :0.036704   Median :0.0140677   Median :0.162582
 Mean   :0.1356624   Mean   :0.124192   Mean   :0.0209195   Mean   :0.272398
 3rd Qu.:0.2327357   3rd Qu.:0.203289   3rd Qu.:0.0435314   3rd Qu.:0.331680
 Max.   :0.3941153   Max.   :0.467615   Max.   :0.0535128   Max.   :0.962963
       V9                V10                 V11
 Min.   :0.01379   Min.   :0.002967   Min.   :0.01082
 1st Qu.:0.02106   1st Qu.:0.111273   1st Qu.:0.07814
 Median :0.30538   Median :0.450790   Median :0.11239
 Mean   :0.47153   Mean   :0.774791   Mean   :0.40253
 3rd Qu.:0.81763   3rd Qu.:1.418243   3rd Qu.:0.53164
 Max.   :1.57432   Max.   :2.449768   Max.   :1.67671
```

幾何ブラウン運動

1. パラメータ設定
2. 各列にシミュレートする。
3. その確率ベクトルを横結合し、確率偏微分方程式を形成する。
4. 結果の目視確認

パラメータ設定

1. 標準偏回帰係数
2. ドリフト項
3. ボラティリティ
4. シミュレーションの設定

In [20]:
```
#標準偏回帰係数
SE_coefficient <- coefficient / SE %>%
  apply(2, as.numeric) %>%
  as.data.frame
#ドリフト項
mean_coefficient <- SE_coefficient %>%
  apply(2, mean) %>%
  as.data.frame
#ボラティリティ
volatility_coefficient <- SE_coefficient %>%
  apply(2, sigma) %>%
  as.data.frame
#シミュレーションの設定
N  <- 2050 - 1987 %>% as.numeric #標本数
t0 <- 1987 %>% as.numeric #開始時(年)
T  <- 2050 %>% as.numeric #終了時(年)
```

パラメータ抽出

1. ドリフト項
2. ボラティリティ

In [21]:
```
#ドリフト項
mean_Y1  <- mean_coefficient[1, ]  %>% as.numeric
mean_Y2  <- mean_coefficient[2, ]  %>% as.numeric
mean_Y3  <- mean_coefficient[3, ]  %>% as.numeric
mean_Y4  <- mean_coefficient[4, ]  %>% as.numeric
mean_Y5  <- mean_coefficient[5, ]  %>% as.numeric
mean_Y6  <- mean_coefficient[6, ]  %>% as.numeric
mean_Y7  <- mean_coefficient[7, ]  %>% as.numeric
mean_Y8  <- mean_coefficient[8, ]  %>% as.numeric
mean_Y9  <- mean_coefficient[9, ]  %>% as.numeric
mean_Y10 <- mean_coefficient[10, ] %>% as.numeric
mean_Y11 <- mean_coefficient[11, ] %>% as.numeric
#ボラティリティ
volatility_Y1  <- volatility_coefficient[1, ]  %>% as.numeric
volatility_Y2  <- volatility_coefficient[2, ]  %>% as.numeric
volatility_Y3  <- volatility_coefficient[3, ]  %>% as.numeric
volatility_Y4  <- volatility_coefficient[4, ]  %>% as.numeric
volatility_Y5  <- volatility_coefficient[5, ]  %>% as.numeric
volatility_Y6  <- volatility_coefficient[6, ]  %>% as.numeric
volatility_Y7  <- volatility_coefficient[7, ]  %>% as.numeric
volatility_Y8  <- volatility_coefficient[8, ]  %>% as.numeric
volatility_Y9  <- volatility_coefficient[9, ]  %>% as.numeric
volatility_Y10 <- volatility_coefficient[10, ] %>% as.numeric
volatility_Y11 <- volatility_coefficient[11, ] %>% as.numeric
```

幾何ブラウン運動の実行

- Y1~11について時間微分係数の期待値を求める。
- 各列について実行する。

In [22]:
```
#時間微分係数の期待値を求める。
SDE_Y1  <- GBM(N = N, t0 = t0, theta = mean_Y1,  sigma = volatility_Y1,  T = T)  #Y1
SDE_Y2  <- GBM(N = N, t0 = t0, theta = mean_Y2,  sigma = volatility_Y2,  T = T)  #Y2
SDE_Y3  <- GBM(N = N, t0 = t0, theta = mean_Y3,  sigma = volatility_Y3,  T = T)  #Y3
SDE_Y4  <- GBM(N = N, t0 = t0, theta = mean_Y4,  sigma = volatility_Y4,  T = T)  #Y4
SDE_Y5  <- GBM(N = N, t0 = t0, theta = mean_Y5,  sigma = volatility_Y5,  T = T)  #Y5
SDE_Y6  <- GBM(N = N, t0 = t0, theta = mean_Y6,  sigma = volatility_Y6,  T = T)  #Y6
SDE_Y7  <- GBM(N = N, t0 = t0, theta = mean_Y7,  sigma = volatility_Y7,  T = T)  #Y7
SDE_Y8  <- GBM(N = N, t0 = t0, theta = mean_Y8,  sigma = volatility_Y8,  T = T)  #Y8
SDE_Y9  <- GBM(N = N, t0 = t0, theta = mean_Y9,  sigma = volatility_Y9,  T = T)  #Y9
SDE_Y10 <- GBM(N = N, t0 = t0, theta = mean_Y10, sigma = volatility_Y10, T = T)  #Y10
SDE_Y11 <- GBM(N = N, t0 = t0, theta = mean_Y11, sigma = volatility_Y11, T = T)  #Y11
```

確率偏微分方程式の形成

1. 各列に実行した幾何ブラウン運動の結果を横結合する。
2. 結果の目視確認を行う。
3. 要約統計量を求める。

In [23]:
```
#横結合
SPDE <- bind_cols(
    SDE_Y1
    , SDE_Y2
    , SDE_Y3
    , SDE_Y4
    , SDE_Y5
    , SDE_Y6
    , SDE_Y7
    , SDE_Y8
    , SDE_Y9
    , SDE_Y10
    , SDE_Y11
) %>%
  apply(2, as.numeric) %>%
  as.data.frame
#列名変更
colnames(SPDE) <- colnames(relation)
#目視確認
SPDE
```

```
New names:
* NA -> ...1
* NA -> ...2
* NA -> ...3
* NA -> ...4
* NA -> ...5
* ...
```

A data.frame: 64 × 11

Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11
<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
0	1.214194e+142	0	0	2.787757e-295	2.787757e-295	2.787757e-295	0	6.826907e-96	2.787757e-295	0
0	4.133972e+141	0	0	3.266796e-296	5.939844e-295	3.088589e-295	0	8.474909e-96	3.020410e-296	0
0	5.680518e+141	0	0	1.924925e-296	2.333422e-295	8.164215e-296	0	3.768269e-96	3.332225e-296	0
0	9.068536e+141	0	0	1.911499e-296	4.138334e-296	8.309882e-296	0	1.216803e-96	2.045401e-296	0
0	6.491479e+141	0	0	9.152112e-297	1.182610e-296	6.051013e-296	0	2.735550e-96	1.275311e-296	0
0	8.626633e+141	0	0	2.746953e-297	4.074779e-297	1.853794e-296	0	3.178792e-96	2.159099e-296	0
0	2.907390e+141	0	0	2.915014e-297	1.044717e-297	1.270394e-297	0	1.558161e-96	1.172482e-296	0
0	5.689126e+141	0	0	1.520802e-297	1.848659e-298	1.396565e-298	0	7.318166e-97	2.193733e-297	0
0	8.422197e+141	0	0	1.370119e-297	1.414571e-298	2.157131e-299	0	1.850876e-97	5.401755e-298	0
0	1.343433e+142	0	0	1.562422e-297	3.666734e-298	3.909599e-299	0	5.626103e-98	4.969202e-298	0
0	1.963395e+142	0	0	1.165156e-297	7.311918e-299	8.074072e-299	0	3.213482e-98	1.425646e-297	0
0	2.937836e+142	0	0	6.429528e-298	4.366383e-299	2.650212e-298	0	1.517392e-97	7.072424e-298	0
0	4.586697e+142	0	0	7.376481e-298	3.759845e-299	1.683173e-298	0	1.701511e-97	4.800539e-298	0
0	4.924456e+142	0	0	1.197895e-297	3.033579e-299	1.879733e-298	0	3.268478e-97	6.406467e-298	0
0	6.274031e+142	0	0	1.345781e-298	8.171912e-300	1.116355e-298	0	4.367118e-97	1.528197e-298	0
0	1.146464e+143	0	0	8.313259e-299	4.131371e-300	7.724724e-299	0	1.366006e-96	1.218856e-298	0
0	6.735473e+142	0	0	8.133384e-299	2.309601e-300	3.534577e-298	0	1.761566e-96	7.827204e-299	0
0	2.785127e+143	0	0	4.668681e-299	6.483988e-301	8.513687e-298	0	1.423775e-96	3.534569e-299	0
0	2.637355e+143	0	0	1.263130e-298	2.858944e-301	5.407387e-298	0	4.708019e-97	2.595134e-299	0
0	4.191093e+143	0	0	5.322464e-299	2.630013e-301	1.568923e-298	0	3.542974e-97	2.002842e-300	0
0	1.860761e+143	0	0	6.988724e-299	3.685076e-301	7.543013e-299	0	1.278071e-97	3.955502e-301	0
0	1.288428e+143	0	0	1.913657e-299	1.117852e-301	5.191190e-299	0	1.238308e-97	8.899072e-302	0
0	1.163756e+143	0	0	6.955880e-300	6.658581e-302	4.879327e-299	0	4.264457e-97	4.291062e-302	0
0	3.760048e+143	0	0	4.515025e-300	5.865524e-301	1.066848e-299	0	2.560566e-97	3.330340e-302	0
0	4.246543e+143	0	0	8.782374e-301	1.499278e-301	3.519326e-300	0	1.427364e-97	3.244767e-302	0
0	5.191312e+143	0	0	1.097417e-301	3.823971e-302	2.622649e-300	0	9.700909e-98	5.594532e-303	0
0	7.010992e+143	0	0	2.180184e-302	1.036853e-302	1.895580e-301	0	1.402514e-97	1.193157e-302	0
0	2.301503e+144	0	0	1.116130e-302	1.645363e-302	6.487082e-302	0	1.055203e-97	1.545247e-302	0
0	5.362575e+144	0	0	1.316369e-303	1.266600e-302	5.099889e-302	0	2.371404e-97	2.350550e-302	0
0	6.643682e+144	0	0	9.263435e-304	3.039875e-302	7.308491e-303	0	5.858961e-97	3.886445e-302	0
...	...	...	...	...	...	...	...	...	...	...
0	2.274851e+143	0	0	1.972459e-305	1.133251e-302	2.951669e-304	0	2.625420e-96	1.505918e-303	0
0	6.649106e+143	0	0	1.486527e-305	5.993107e-303	1.564650e-305	0	4.367747e-96	1.599935e-303	0
0	2.028560e+144	0	0	2.457973e-305	4.510684e-303	2.444390e-306	0	1.666321e-96	1.764040e-304	0
0	4.770517e+144	0	0	1.200340e-305	1.275104e-304	8.985445e-306	0	1.191096e-96	3.716448e-304	0
0	5.385745e+144	0	0	1.734870e-305	4.017162e-305	7.967693e-306	0	4.554666e-97	8.257543e-305	0
0	1.754441e+145	0	0	1.211206e-306	1.504632e-304	1.584009e-305	0	1.738000e-96	3.302062e-304	0
0	3.292832e+145	0	0	1.086977e-306	1.408875e-304	2.453603e-305	0	3.133587e-97	2.181093e-304	0
0	3.127287e+145	0	0	3.824501e-307	2.788557e-305	2.667214e-305	0	5.367967e-98	8.987112e-305	0
0	3.473154e+145	0	0	1.079168e-307	2.195801e-305	5.562284e-306	0	3.227509e-98	2.085755e-305	0
0	6.175739e+145	0	0	7.088563e-308	2.012136e-305	8.887277e-306	0	2.315584e-98	1.179048e-305	0
0	4.609363e+145	0	0	3.836282e-308	1.527368e-305	4.892176e-306	0	1.719304e-97	7.458071e-306	0
0	6.212359e+145	0	0	2.589835e-308	1.401808e-305	4.152540e-306	0	6.200939e-97	9.411740e-306	0
0	1.866404e+145	0	0	9.729905e-309	4.973264e-306	5.932756e-306	0	6.860489e-96	5.116610e-306	0
0	2.505258e+145	0	0	6.140306e-309	1.194196e-306	1.402225e-305	0	4.777367e-96	1.022420e-305	0
0	2.137613e+145	0	0	1.310548e-308	6.514859e-307	3.424565e-306	0	1.521874e-95	2.539981e-306	0
0	3.324482e+145	0	0	5.730077e-309	1.800392e-307	1.464333e-306	0	2.520386e-95	3.806488e-307	0
0	1.626421e+146	0	0	1.062747e-309	9.174795e-308	6.336254e-307	0	2.616591e-95	5.640131e-307	0
0	3.095471e+146	0	0	2.550817e-310	1.036256e-307	5.356706e-307	0	1.022733e-94	7.481744e-307	0
0	4.404557e+146	0	0	8.495617e-311	1.602704e-307	3.679543e-307	0	4.567477e-95	1.015604e-306	0

Y1	Y2	Y3	Y4	Y5	Y6	Y7	Y8	Y9	Y10	Y11
<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>	<dbl>
0	3.590938e+146	0	0	2.551335e-311	3.439900e-307	8.852829e-307	0	1.045618e-94	2.112730e-306	0
0	1.083830e+146	0	0	1.592664e-311	1.375234e-307	1.611067e-307	0	5.365368e-95	6.184044e-306	0
0	1.907798e+146	0	0	7.536309e-312	8.978749e-308	1.147383e-307	0	4.138386e-95	3.802603e-306	0
0	2.550076e+146	0	0	5.595942e-312	1.901073e-307	1.181876e-307	0	1.232250e-95	5.760028e-306	0
0	6.326700e+146	0	0	2.566766e-312	2.925832e-307	6.208100e-308	0	6.380427e-96	1.523416e-305	0
0	1.106675e+147	0	0	2.470169e-313	8.488189e-308	1.909217e-308	0	3.346930e-96	8.550474e-306	0
0	1.877841e+147	0	0	8.057936e-314	3.067900e-308	6.372203e-308	0	6.507873e-96	1.648091e-305	0
0	1.698578e+147	0	0	9.802376e-314	4.871468e-309	6.185313e-308	0	6.874906e-96	9.943816e-306	0
0	2.204589e+147	0	0	7.704980e-314	1.416572e-309	1.306769e-308	0	4.367821e-95	1.731673e-304	0
0	2.747394e+147	0	0	7.747987e-314	4.572720e-310	1.238614e-308	0	9.955506e-96	7.198074e-304	0
0	3.590484e+147	0	0	4.879711e-314	2.832750e-310	3.475210e-309	0	3.208301e-96	5.130536e-304	0

In [24]:
```
#要約統計量を求める。
SPDE %>%
  summary
```

```
       Y1          Y2                   Y3          Y4          Y5           
 Min.   :0   Min.   :2.907e+141   Min.   :0   Min.   :0   Min.   : 0.000e+00  
 1st Qu.:0   1st Qu.:1.028e+143   1st Qu.:0   1st Qu.:0   1st Qu.: 0.000e+00  
 Median :0   Median :1.565e+144   Median :0   Median :0   Median : 0.000e+00  
 Mean   :0   Mean   :2.517e+146   Mean   :0   Mean   :0   Mean   :5.835e-297  
 3rd Qu.:0   3rd Qu.:5.001e+145   3rd Qu.:0   3rd Qu.:0   3rd Qu.:9.393e-299  
 Max.   :0   Max.   :3.590e+147   Max.   :0   Max.   :0   Max.   :2.788e-295  
       Y6                  Y7                  Y8          Y9           
 Min.   : 0.000e+00   Min.   : 0.000e+00   Min.   :0   Min.   :2.316e-98  
 1st Qu.: 0.000e+00   1st Qu.: 0.000e+00   1st Qu.:0   1st Qu.:1.818e-97  
 Median : 0.000e+00   Median : 0.000e+00   Median :0   Median :1.204e-96  
 Mean   :1.821e-296   Mean   :1.306e-296   Mean   :0   Mean   :8.902e-96  
 3rd Qu.:2.800e-300   3rd Qu.:8.846e-299   3rd Qu.:0   3rd Qu.:6.412e-96  
 Max.   :5.940e-295   Max.   :3.089e-295   Max.   :0   Max.   :1.046e-94  
      Y10                 Y11   
 Min.   : 0.000e+00   Min.   :0  
 1st Qu.: 0.000e+00   1st Qu.:0  
 Median :1.000e-302   Median :0  
 Mean   :6.496e-297   Mean   :0  
 3rd Qu.:8.918e-299   3rd Qu.:0  
 Max.   :2.788e-295   Max.   :0  
```

LSTM(Long Short Term Memory)

- 時系列予測の精度評価を行う。
- 時系列データ向けのDeepLearningである。

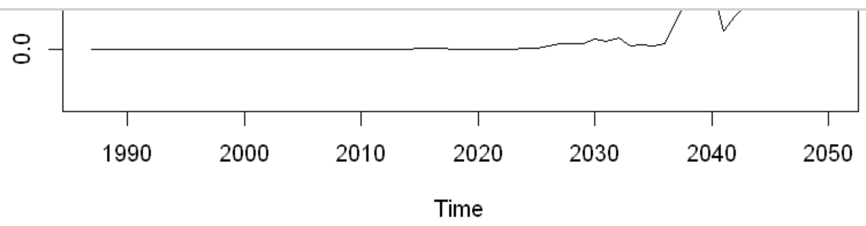
出力保存先の相対パス指定

In [25]:
```
setwd("./1_output")
```

関数定義の実行

- 確率ベクトル毎に実行する。
- LSTM(Long Short Term Memory)による幾何ブラウン運動の精度評価
- 値が0以外の確率過程について精度評価を行う。
- グラフ描画も関数定義に含む。

In [26]:
```
LSTM(SDE_Y2,  10)
ggsave("LSTM_Y2.jpg")
LSTM(SDE_Y5,  10)
ggsave("LSTM_Y5.jpg")
LSTM(SDE_Y6,  10)
ggsave("LSTM_Y6.jpg")
LSTM(SDE_Y7,  10)
ggsave("LSTM_Y7.jpg")
LSTM(SDE_Y9,  10)
ggsave("LSTM_Y9.jpg")
LSTM(SDE_Y10, 10)
ggsave("LSTM_Y10.jpg")
```




```
Saving 6.67 x 6.67 in image
```

結果.csvの出力

In [27]:
```
fwrite(SPDE, "panel_VAR_SPDE_LSTM_model.csv")
```

グラフ描画・出力

1. ローデータの多変量時系列プロット
2. 誤差項調整した多変量時系列プロット
3. 相関行列の可視化による多重共線性の目視確認

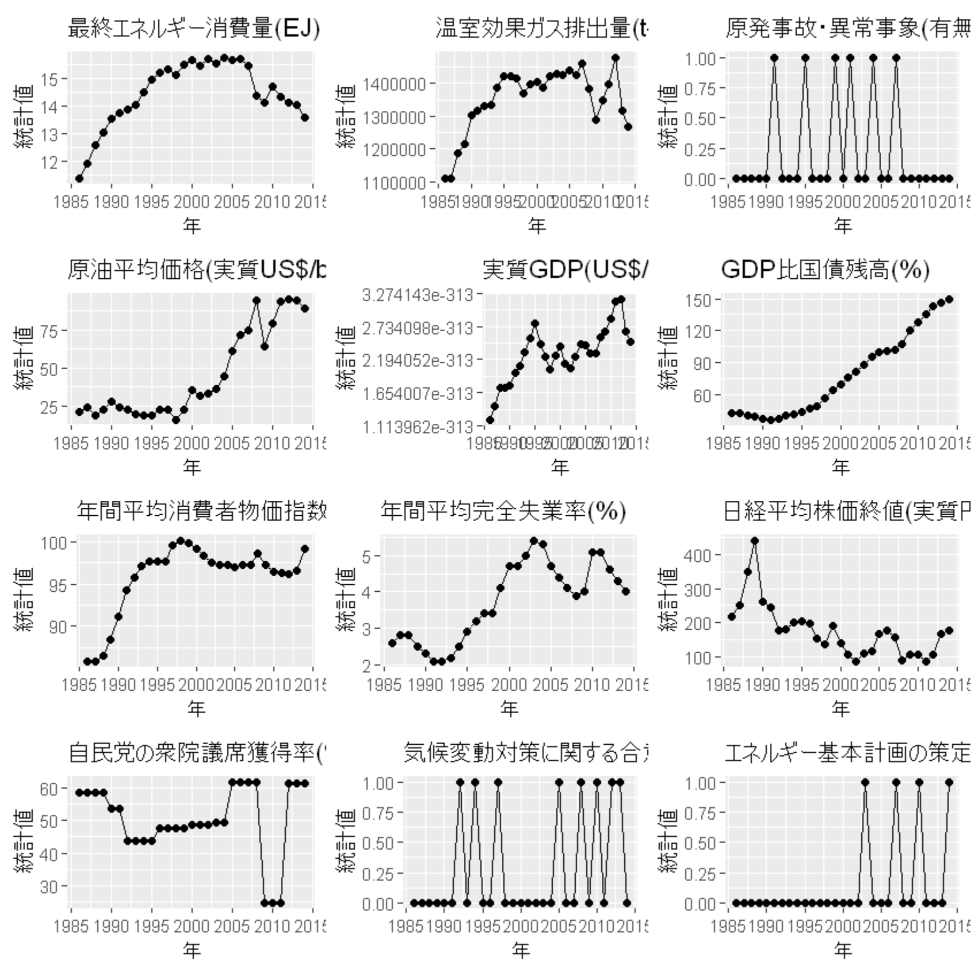
ローデータの多変量時系列プロット

In [28]:

```
#各グラフの作成
fig_1  <- fig(raw_data, raw_data$Y1, "最終エネルギー消費量(EJ)", "統計値")
fig_2  <- fig(raw_data, raw_data$Y2, "温室効果ガス排出量(t-CO2換算)", "統計値")
fig_3  <- fig(raw_data, raw_data$Y3,  "原発事故・異常事象(有無)", "統計値")
fig_4  <- fig(raw_data, raw_data$Y4, "原油平均価格(実質US$/bbl)", "統計値")
fig_5  <- fig(raw_data, raw_data$Y5, "実質GDP(US$/消費者物価指数: 2015年 = 1)", "統計値")
fig_6  <- fig(raw_data, raw_data$Y6, "GDP比国債残高(%)", "統計値")
fig_7  <- fig(raw_data, raw_data$Y7, "年間平均消費者物価指数(2015年 = 100)", "統計値")
fig_8  <- fig(raw_data, raw_data$Y8, "年間平均完全失業率(%)","統計値")
fig_9  <- fig(raw_data, raw_data$Y9, "日経平均株価終値(実質円)", "統計値")
fig_10 <- fig(raw_data, raw_data$Y10, "自民党の衆院議席獲得率(%)", "統計値")
fig_11 <- fig(raw_data, raw_data$Y11, "気候変動対策に関する合意(有無)", "統計値")
fig_12 <- fig(raw_data, raw_data$id,  "エネルギー基本計画の策定・改正(有無)", "統計値")
#一枚に集約して出力する。
grid.arrange(fig_1, fig_2, fig_3, fig_4, fig_5, fig_6, fig_7, fig_8, fig_9, fig_10, fig_11, fig_12)
ggsave("Multivariate_Time_Series_Plot_raw_data.jpg")
```

```
Don't know how to automatically pick scale for object of type integer64. Defaulting to continuous.

Saving 6.67 x 6.67 in image
```



誤差項調整した多変量時系列プロット

In [29]:

```
#各グラフの作成
fig_1  <- fig(panel, panel$Y1,  "最終エネルギー消費量(EJ)", "対数差分系列")
fig_2  <- fig(panel, panel$Y2,  "温室効果ガス排出量(t-CO2換算)", "対数差分系列")
fig_3  <- fig(panel, panel$Y3,  "原発事故・異常事象(有無)", "対数差分プロビット写像")
fig_4  <- fig(panel, panel$Y4,  "原油平均価格(実質US$/bbl)", "対数差分系列")
fig_5  <- fig(panel, panel$Y5,  "実質GDP(US$/消費者物価指数: 2015年 = 1)", "対数差分系列")
fig_6  <- fig(panel, panel$Y6,  "GDP比国債残高(%)", "対数差分系列")
fig_7  <- fig(panel, panel$Y7,  "年間平均消費者物価指数(2015年 = 100)","対数差分系列")
fig_8  <- fig(panel, panel$Y8,  "年間平均完全失業率(%)", "対数差分系列")
fig_9  <- fig(panel, panel$Y9,  "日経平均株価終値(実質円)", "対数差分系列")
fig_10 <- fig(panel, panel$Y10, "自民党の衆院議席獲得率(%)", "対数差分系列")
fig_11 <- fig(panel, panel$Y11, "気候変動対策に関する合意(有無)", "対数差分プロビット写像")
fig_12 <- fig(panel, panel$id,  "エネルギー基本計画の策定・改正(有無)", "対数差分系列")
#一枚に集約して出力する。
grid.arrange(fig_1, fig_2, fig_3, fig_4, fig_5, fig_6, fig_7, fig_8, fig_9, fig_10, fig_11, fig_12)
ggsave("Multivariate_Time_Series_Plot_adjusted.jpg")
```

```
geom_path: Each group consists of only one observation. Do you need to adjust
the group aesthetic?

geom_path: Each group consists of only one observation. Do you need to adjust
the group aesthetic?

geom_path: Each group consists of only one observation. Do you need to adjust
the group aesthetic?

geom_path: Each group consists of only one observation. Do you need to adjust
the group aesthetic?

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```
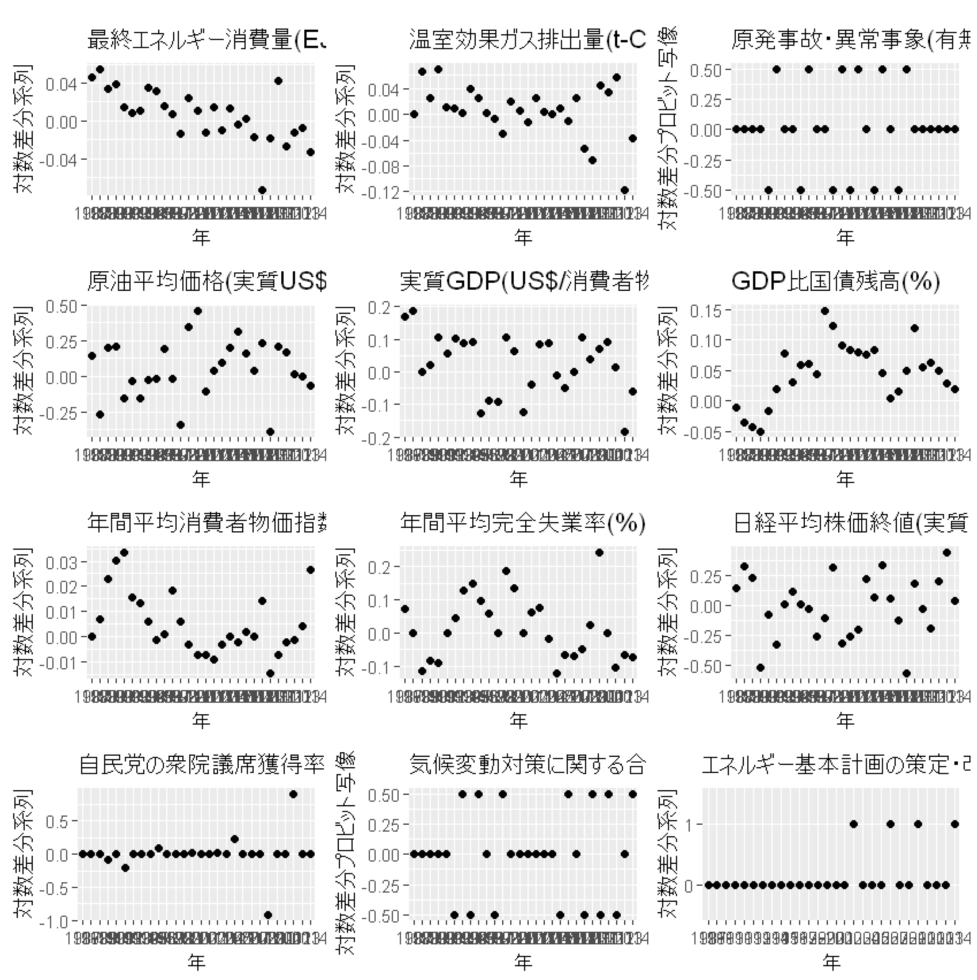
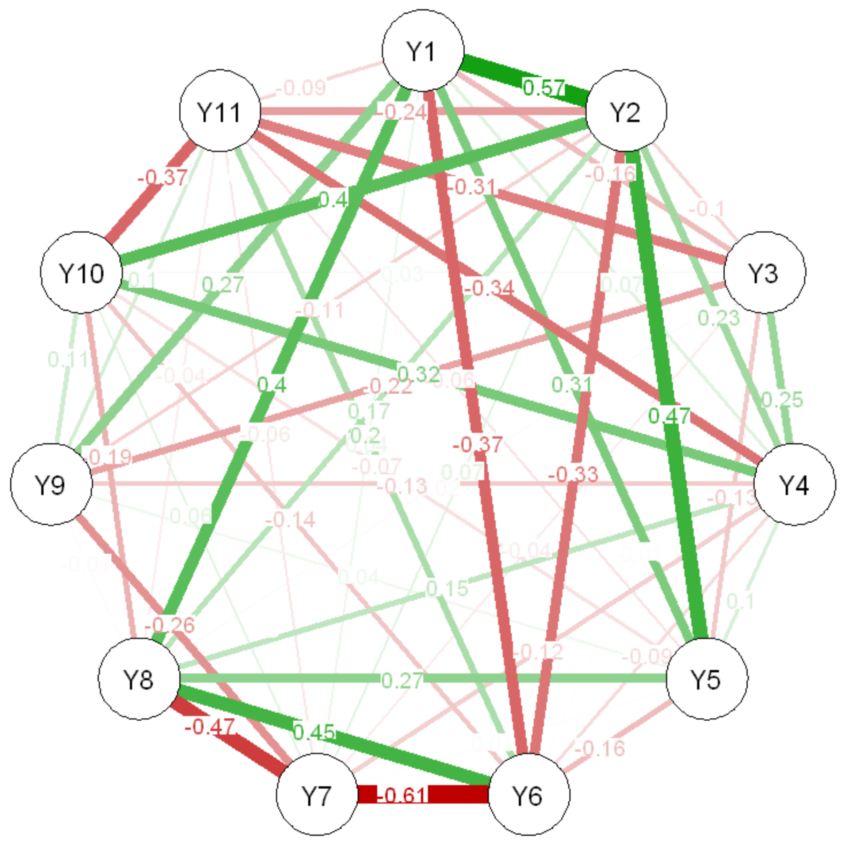



相関行列の可視化による多重共線性の目視確認

In [30]:
```
qgraph(cor(relation), edge.labels = TRUE)
ggsave("relation_vector.jpg")
```

```
Saving 6.67 x 6.67 in image

geom_path: Each group consists of only one observation. Do you need to adjust
the group aesthetic?
```



幾何ブラウン運動の多変量時系列プロット

In [31]:
```r
#classをtsからdata.frameに変換し、グラフの規格化を図る。
plot_SDE_Y1  <- SDE_Y1  %>% ts_df
plot_SDE_Y2  <- SDE_Y2  %>% ts_df
plot_SDE_Y3  <- SDE_Y3  %>% ts_df
plot_SDE_Y4  <- SDE_Y4  %>% ts_df
plot_SDE_Y5  <- SDE_Y5  %>% ts_df
plot_SDE_Y6  <- SDE_Y6  %>% ts_df
plot_SDE_Y7  <- SDE_Y7  %>% ts_df
plot_SDE_Y8  <- SDE_Y8  %>% ts_df
plot_SDE_Y9  <- SDE_Y9  %>% ts_df
plot_SDE_Y10 <- SDE_Y10 %>% ts_df
plot_SDE_Y11 <- SDE_Y11 %>% ts_df
#各グラフの作成
fig_1  <- fig(plot_SDE_Y1,plot_SDE_Y1$value,   "最終エネルギー消費量(EJ)","時間微分係数の期待値")
fig_2  <- fig(plot_SDE_Y2,plot_SDE_Y2$value,   "温室効果ガス排出量(t-CO2換算)","時間微分係数の期待値")
fig_3  <- fig(plot_SDE_Y3,plot_SDE_Y3$value,   "原発事故・異常事象(有無)","時間微分係数の期待値")
fig_4  <- fig(plot_SDE_Y4,plot_SDE_Y4$value,   "原油平均価格(実質US$/bbl)","時間微分係数の期待値")
fig_5  <- fig(plot_SDE_Y5,plot_SDE_Y5$value,   "実質GDP(US$/消費者物価指数: 2015年 = 1)","時間微分係数の期待値")
fig_6  <- fig(plot_SDE_Y6,plot_SDE_Y6$value,   "GDP比国債残高(%)","時間微分係数の期待値")
fig_7  <- fig(plot_SDE_Y7,plot_SDE_Y7$value,   "年間平均消費者物価指数(2015年 = 100)","時間微分係数の期待値")
fig_8  <- fig(plot_SDE_Y8,plot_SDE_Y8$value,   "年間平均完全失業率(%)","時間微分係数の期待値")
fig_9  <- fig(plot_SDE_Y9,plot_SDE_Y9$value,   "日経平均株価終値(実質円)","時間微分係数の期待値")
fig_10 <- fig(plot_SDE_Y10,plot_SDE_Y10$value, "自民党の衆院議席獲得率(%)","時間微分係数の期待値")
fig_11 <- fig(plot_SDE_Y11,plot_SDE_Y11$value, "気候変動対策に関する合意(有無)","時間微分係数の期待値")
#一枚に集約して出力する。
grid.arrange(fig_1, fig_2, fig_3, fig_4, fig_5, fig_6, fig_7, fig_8, fig_9, fig_10, fig_11)
ggsave("Multivariate_Time_Series_Plot_GBM.jpg")
```

```
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```