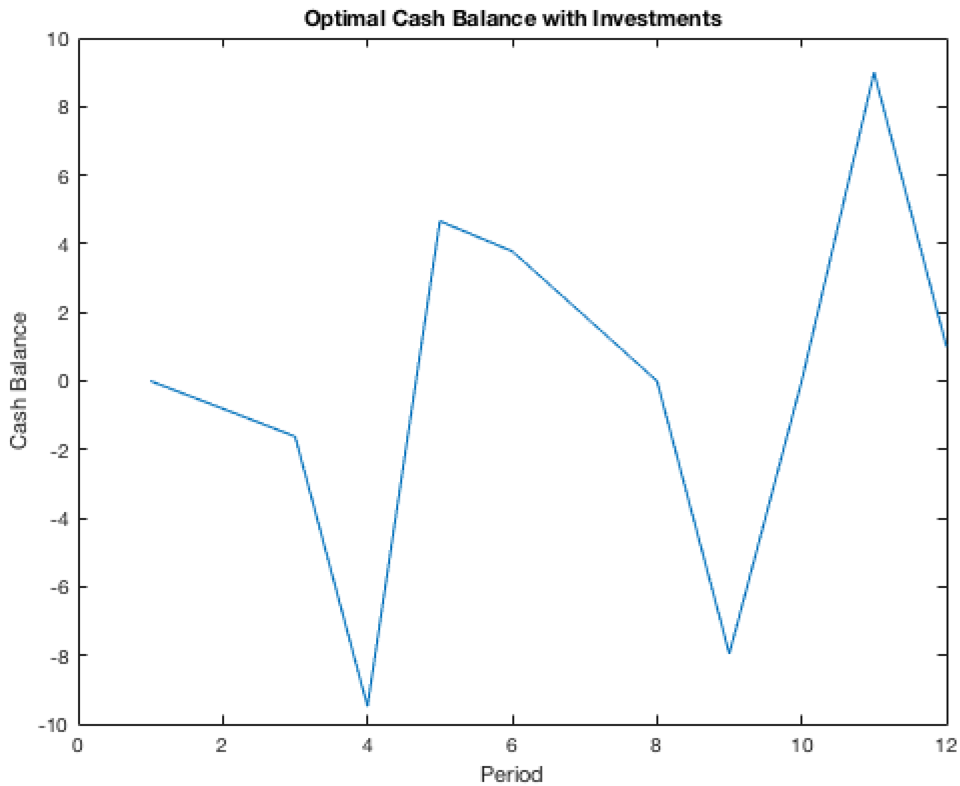
```matlab
clear all;

final19_q7_data;

cvx_begin
    variables x(n) B0
    minimize(P'*x+B0)
    subject to
        -x <= 0
        -B0 <= 0
        B(1) = (1+rp)*B0
        for t=1:T-1
            B(t+1)= min((1+rp)*(B(t)+A(t,:)*x-E(t)),
(1+rn)*(B(t)+A(t,:)*x-E(t)))
        end
        E(T)-B(T)-A(T,:)*x <= 0
cvx_end

% Compare to investment if no bonds were purchased

cvx_begin
    variable D0
    minimize(D0)
    subject to
        -D0 <= 0
        D(1) = (1+rp)*D0
        for t=1:T-1
            D(t+1)=min((1+rp)*(D(t)-E(t)),(1+rn)*(D(t)-E(t)));
        end
        E(T)-D(T) <= 0
cvx_end

disp("Optimal values of x:")
disp(x)
disp("Optimal value of B0:")
disp(B0)
disp("Optimal total initial investment:")
disp(P'*x+B0)
disp("Optimal investment without bonds:")
disp(D0)

figure(1)
plot(1:T,B)
title('Optimal Cash Balance with Investments')
xlabel('Period')
ylabel('Cash Balance')

figure(2)
plot(1:T,D)
title('Optimal Cash Balance without Investments')
xlabel('Period')
ylabel('Cash Balance')
```

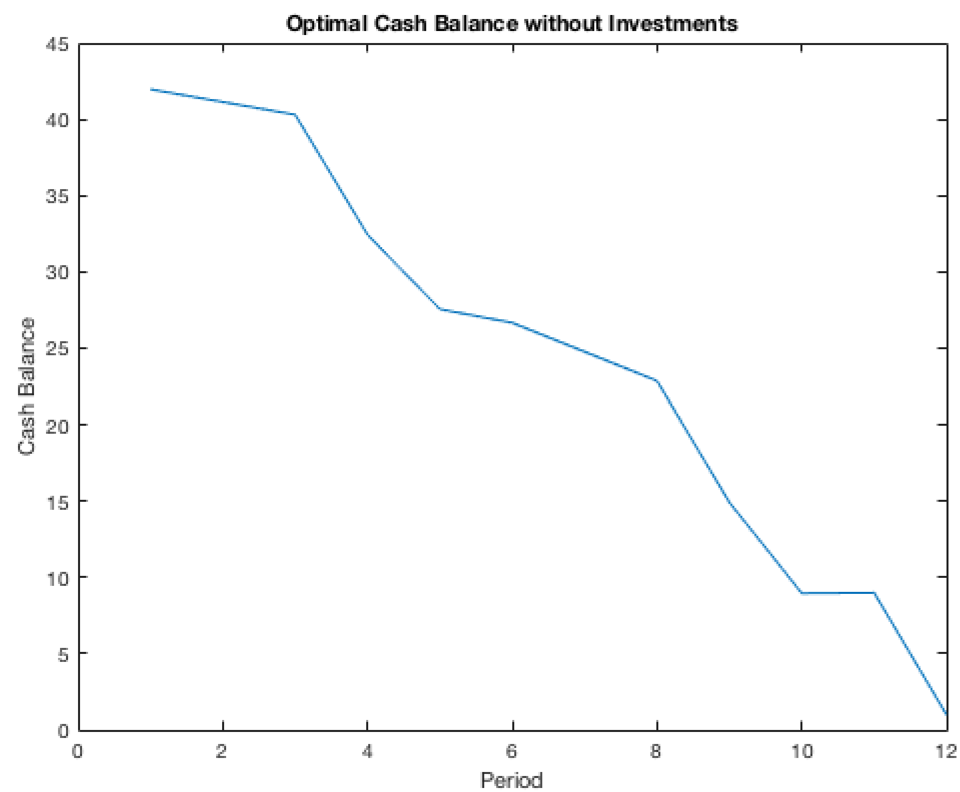
```
B =

    cvx real affine expression (scalar)

B =

    cvx mixed concave/real affine expression (1x2 vector)

B =

    cvx mixed concave/real affine expression (1x3 vector)

B =

    cvx mixed concave/real affine expression (1x4 vector)

B =

    cvx mixed concave/real affine expression (1x5 vector)

B =

    cvx mixed concave/real affine expression (1x6 vector)

B =

    cvx mixed concave/real affine expression (1x7 vector)

B =

    cvx mixed concave/real affine expression (1x8 vector)

B =

    cvx mixed concave/real affine expression (1x9 vector)

B =

    cvx mixed concave/real affine expression (1x10 vector)

B =

    cvx mixed concave/real affine expression (1x11 vector)
```

```
B =

    cvx mixed concave/real affine expression (1x12 vector)


Calling SDPT3 4.0: 30 variables, 18 equality constraints
   For improved efficiency, SDPT3 is solving the dual problem.
------------------------------------------------------------

 num. of constraints = 18
 dim. of linear var  = 30
*******************************************************************
   SDPT3: Infeasible path-following algorithms
*******************************************************************
 version  predcorr  gam  expon  scale_data
    NT      1      0.000   1        0
it pstep dstep pinfeas dinfeas  gap      prim-obj      dual-obj
 cputime
-------------------------------------------------------------------
 0|0.000|0.000|2.2e+01|6.2e+00|7.4e+03|-8.638509e+02  0.000000e+00|
 0:0:00| chol  1  1
 1|0.978|1.000|4.9e-01|2.2e-02|4.5e+02|-5.247813e+01 -3.011420e+02|
 0:0:00| chol  1  1
 2|1.000|1.000|3.5e-07|2.2e-03|4.6e+01|-3.279908e+01 -7.859801e+01|
 0:0:00| chol  1  1
 3|1.000|0.929|7.7e-08|3.6e-04|3.1e+00|-3.876965e+01 -4.181308e+01|
 0:0:00| chol  1  1
 4|0.908|0.918|3.9e-07|5.0e-05|3.3e-01|-4.063267e+01 -4.095806e+01|
 0:0:00| chol  1  1
 5|0.598|1.000|5.2e-07|2.2e-06|1.7e-01|-4.068372e+01 -4.085830e+01|
 0:0:01| chol  1  1
 6|0.930|0.772|1.4e-07|7.1e-07|4.4e-02|-4.073543e+01 -4.077891e+01|
 0:0:01| chol  1  1
 7|0.951|1.000|3.6e-08|5.1e-08|1.9e-02|-4.074352e+01 -4.076239e+01|
 0:0:01| chol  1  1
 8|0.937|0.963|1.1e-08|1.1e-08|9.3e-04|-4.074909e+01 -4.075002e+01|
 0:0:01| chol  2  2
 9|0.981|0.955|1.4e-07|2.6e-09|5.2e-05|-4.074949e+01 -4.074954e+01|
 0:0:01| chol  2  2
10|0.988|0.988|1.7e-09|1.2e-09|6.8e-07|-4.074950e+01 -4.074950e+01|
 0:0:01|
  stop: max(relative gap, infeasibilities) < 1.49e-08
-------------------------------------------------------------------
 number of iterations   = 10
 primal objective value = -4.07495028e+01
 dual   objective value = -4.07495034e+01
 gap := trace(XZ)       = 6.78e-07
 relative gap           = 8.22e-09
 actual relative gap    = 7.03e-09
 rel. primal infeas (scaled problem)   = 1.71e-09
 rel. dual     "        "       "      = 1.23e-09
 rel. primal infeas (unscaled problem) = 0.00e+00
```

```
 rel. dual     "        "       "      = 0.00e+00
 norm(X), norm(y), norm(Z) = 3.2e+00, 2.9e+01, 2.5e+01
 norm(A), norm(b), norm(C) = 9.0e+00, 3.6e+00, 2.5e+01
 Total CPU time (secs)  = 0.59
 CPU time per iteration = 0.06
 termination code       =  0
 DIMACS: 3.1e-09  0.0e+00  3.1e-09  0.0e+00  7.0e-09  8.2e-09
-------------------------------------------------------------------

------------------------------------------------------------
Status: Solved
Optimal value (cvx_optval): +40.7495


D =

    cvx real affine expression (scalar)


Calling SDPT3 4.0: 24 variables, 12 equality constraints
   For improved efficiency, SDPT3 is solving the dual problem.
------------------------------------------------------------

 num. of constraints = 12
 dim. of linear var  = 24
*******************************************************************
   SDPT3: Infeasible path-following algorithms
*******************************************************************
 version  predcorr  gam  expon  scale_data
    NT      1      0.000   1        0
it pstep dstep pinfeas dinfeas  gap      prim-obj      dual-obj
 cputime
-------------------------------------------------------------------
 0|0.000|0.000|1.5e+01|5.6e+00|7.0e+03|-8.630333e+02  0.000000e+00|
 0:0:00| chol  1  1
 1|0.364|1.000|9.8e+00|1.7e-02|3.3e+03|-7.994290e+02 -2.122809e+02|
 0:0:00| chol  1  1
 2|1.000|1.000|4.3e-06|1.7e-03|1.6e+02|-4.021972e+01 -1.954105e+02|
 0:0:00| chol  1  1
 3|1.000|0.978|7.2e-07|2.0e-04|3.4e+00|-4.065878e+01 -4.402331e+01|
 0:0:00| chol  1  1
 4|0.974|0.925|2.4e-07|3.1e-05|4.2e-01|-4.153863e+01 -4.195341e+01|
 0:0:00| chol  1  1
 5|0.955|0.944|2.9e-08|3.3e-06|5.0e-02|-4.176869e+01 -4.181810e+01|
 0:0:00| chol  1  1
 6|0.986|0.884|5.3e-09|5.4e-07|5.6e-03|-4.178863e+01 -4.179415e+01|
 0:0:00| chol  1  1
 7|0.976|0.981|1.7e-09|1.1e-08|1.7e-04|-4.179018e+01 -4.179035e+01|
 0:0:00| chol  1  1
 8|0.989|0.989|2.9e-10|4.8e-10|2.0e-06|-4.179024e+01 -4.179024e+01|
 0:0:00| chol  1  1
 9|0.996|0.996|2.6e-12|4.3e-11|3.2e-08|-4.179024e+01 -4.179024e+01|
 0:0:00|
  stop: max(relative gap, infeasibilities) < 1.49e-08
```

```
-------------------------------------------------------------------
 number of iterations   =  9
 primal objective value = -4.17902433e+01
 dual   objective value = -4.17902434e+01
 gap := trace(XZ)       = 3.20e-08
 relative gap           = 3.79e-10
 actual relative gap    = 3.46e-10
 rel. primal infeas (scaled problem)   = 2.63e-12
 rel. dual     "        "       "      = 4.35e-11
 rel. primal infeas (unscaled problem) = 0.00e+00
 rel. dual     "        "       "      = 0.00e+00
 norm(X), norm(y), norm(Z) = 3.4e+00, 7.1e+01, 4.2e+01
 norm(A), norm(b), norm(C) = 7.8e+00, 2.0e+00, 2.9e+01
 Total CPU time (secs)  = 0.14
 CPU time per iteration = 0.02
 termination code       =  0
 DIMACS: 2.6e-12  0.0e+00  9.1e-11  0.0e+00  3.5e-10  3.8e-10
-------------------------------------------------------------------

------------------------------------------------------------
Status: Solved
Optimal value (cvx_optval): +41.7902

Optimal values of x:
    0.0000
   18.9324
    0.0000
    0.0000
   13.8495
    8.9228

Optimal value of B0:
   1.7792e-06

Optimal total initial investment:
   40.7495

Optimal investment without bonds:
   41.7902
```


Optimal Cash Balance with Investments
Cash Balance
Period
10
8
6
4
2
0
-2
-4
-6
-8
-10
0
2
4
6
8
10
12


Optimal Cash Balance without Investments
Cash Balance
Period
45
40
35
30
25
20
15
10
5
0
0
2
4
6
8
10
12

Published with MATLAB® R2018b