

a) Formulate QP problem.

```
sigma = [  
    0.2 -0.2 -0.12 0.02;  
    -0.2 1.4 0.02 0;  
    -0.12 0.02 1 -0.4;  
    0.02 0 -0.4 0.2  
];  
  
expectation = [1.1 1.35 1.25 1.05]';  
  
Aeq = ones(4,1)';  
beq = 1;  
  
A = [-expectation'; -eye(4)];  
  
f = zeros(1,4);
```

```
figure  
for rmin = 0:0.2:2  
    bneq = [-rmin, zeros(1,4)]';  
    p = quadprog(sigma, f, A, bneq, Aeq, beq);  
    risk = p'*sigma*p;  
    exp_return = p'*expectation;  
    scatter(exp_return, risk);  
    hold on  
end
```

Minimum found that satisfies the constraints.

Optimization completed because the objective function is non-decreasing in feasible directions, to within the value of the optimality tolerance, and constraints are satisfied to within the value of the constraint tolerance.

<stopping criteria details>

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quadprog stopped because it was unable to find a point that satisfies the constraints within the value of the constraint tolerance.

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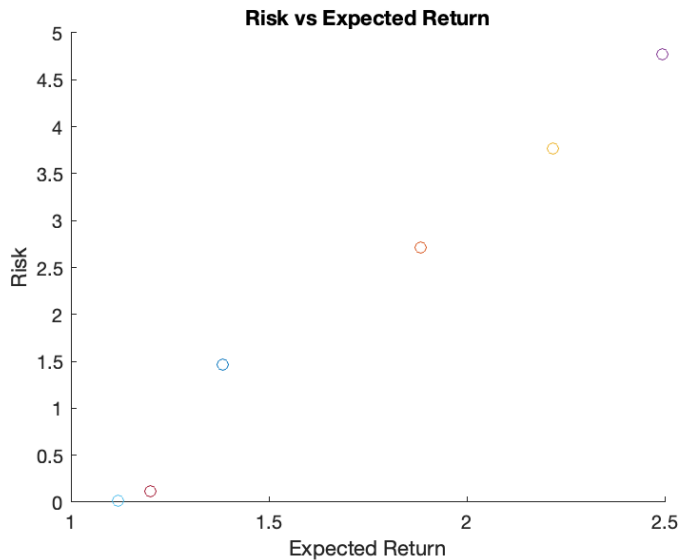
<stopping criteria details>

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```
title('Risk vs Expected Return')
xlabel('Expected Return');
ylabel('Risk')
```



Risk increases approximately linearly with return.

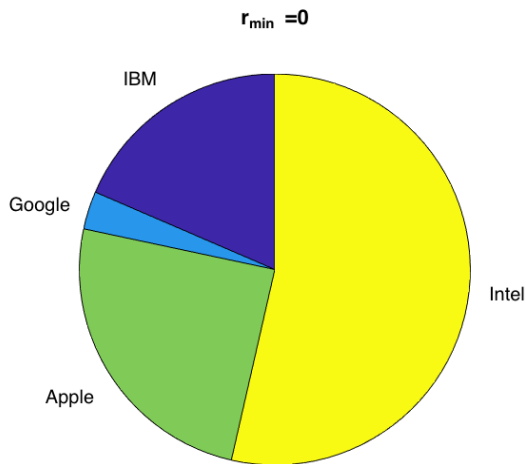
b) Plot portfolio allocation

```
labels = {'IBM', 'Google', 'Apple', 'Intel'};
for rmin = 0:0.2:2
    figure
    bneq = [-rmin, zeros(1,4)]';
    p = quadprog(sigma, f, A, bneq, Aeq, beq);
    pie(p, labels);
    title(strcat('r_{min} = ', num2str(rmin)));
end
```

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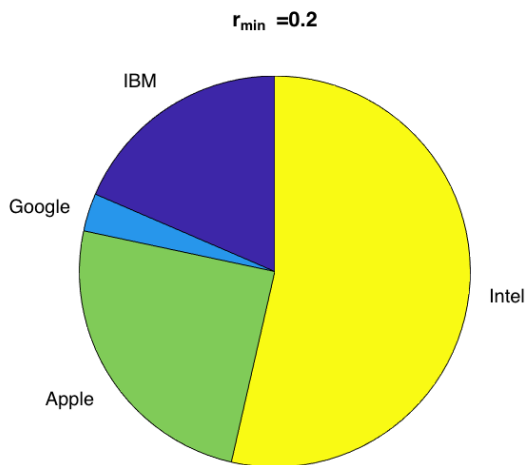
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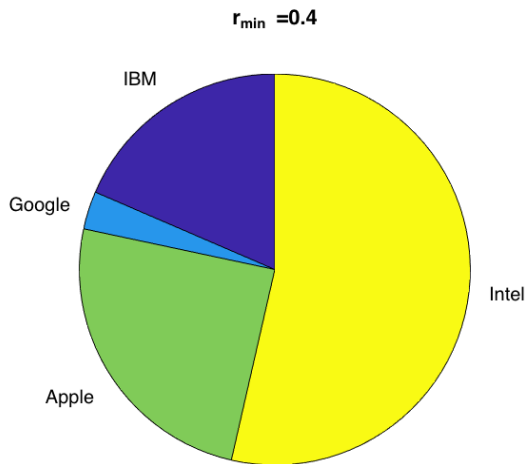
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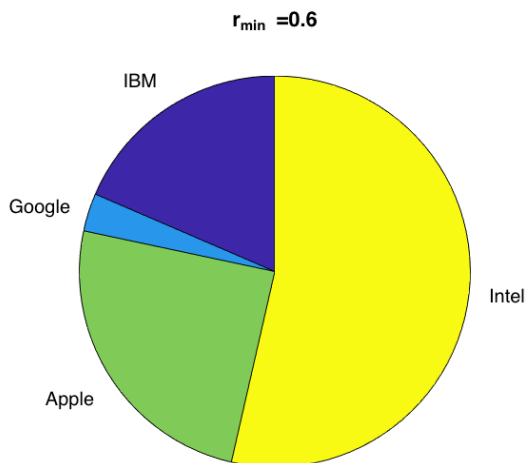
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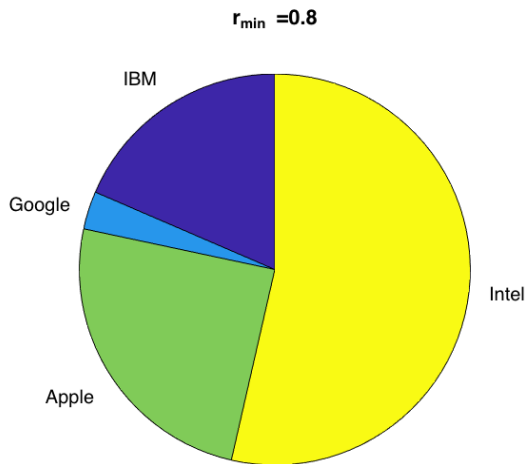
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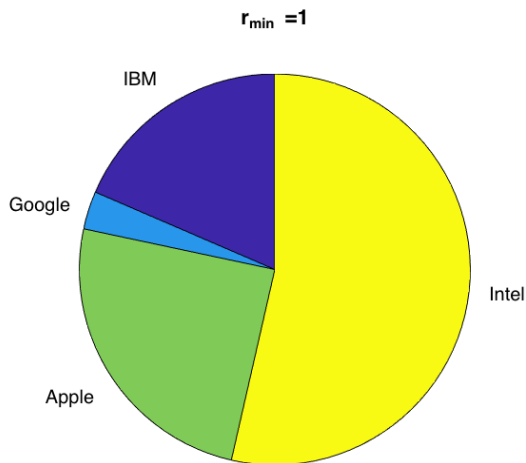
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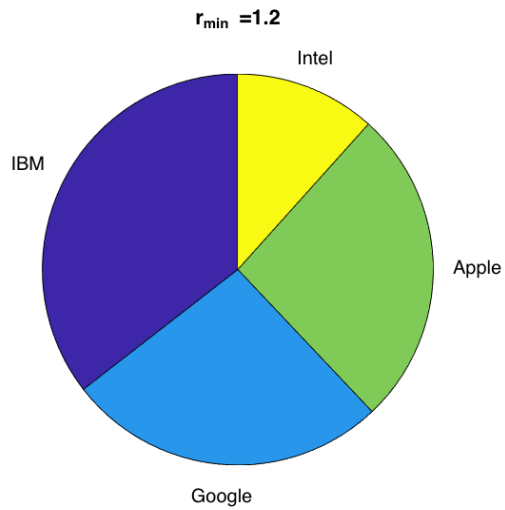
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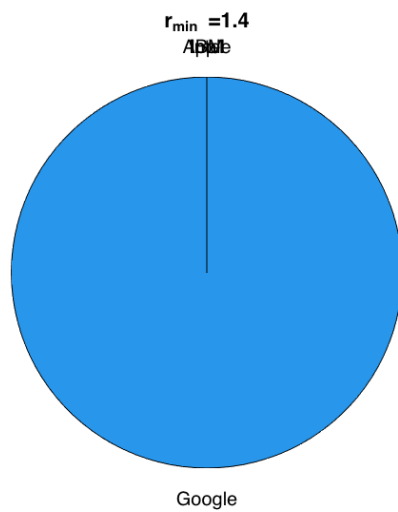
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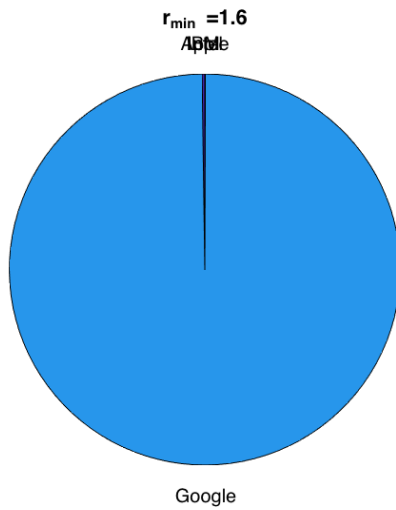
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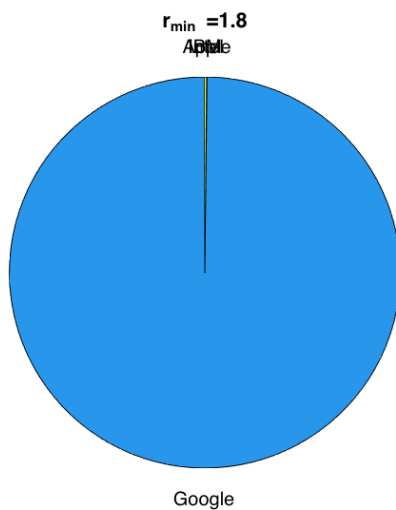
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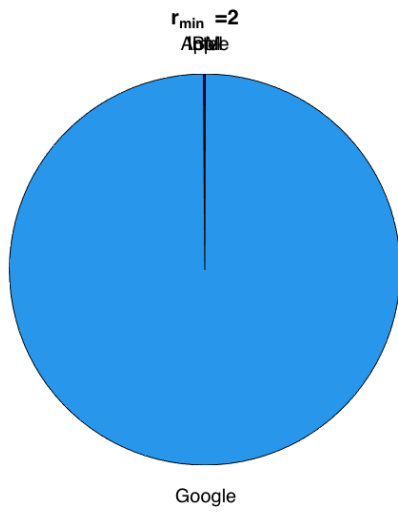


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```
xlabel('Expected Return');
ylabel('Risk')
```

For low r_{\min} , we invest heavily in Intel to minimize risk.

For higher r_{\min} , we require more risky investments in Google and Apple. Allocation for Intel decreases as a result.