Characteristics of the NAREIT Index Compared to Private Real Estate

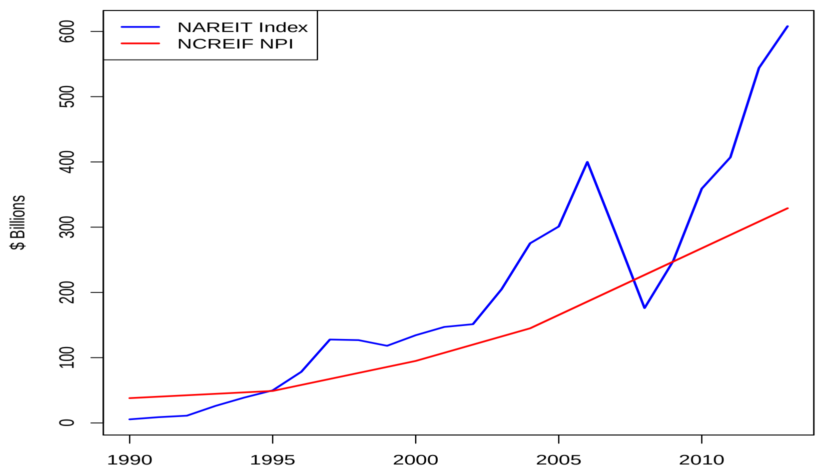
October 9, 2014

1 Background

The ASRS strategic asset allocation and the real estate strategic plan provide guidance for the ASRS real estate program. Under these plans, ASRS has allocated eight percent of total assets to real estate. The plans permit, but do not require, investment in REITs as part of the real estate portfolio. ASRS currently holds less than $100 million of real estate program in publicly traded REITs.

The purpose of this paper is to consider whether REITs should play a larger or different role in our portfolio. We consider here the characteristics of the NAREIT index compared to private real estate and whether a passive implementation of REITs would be beneficial to the ASRS real estate program and total portfolio. In a subsequent writing we will consider active and tactical approaches to REITs.

Figure 1: Index Market Capitalization



2 The Indices

REITs are corporations that own real estate and are organized under tax laws to enjoy tax exempt status. REITs can be public or private, but we confine our focus here to public REITs.

In order to compare REITs to private real estate, we are using two indices. The FTSE NAREIT all equity REIT total return index (FNERTR bbg ticker) is a market cap weighted index of total return for all equity REITs listed on the NYSE, AMEX and NASDAQ exchanges. The NCREIF NPI total return index (NPPITR bbg ticker) is a market cap weighted appraisal based index of unlevered property returns of investment properties in tax exempt institutional ownership. The total market capitalization of REITs and the total value of properties included in NCREIF are shown in the graph in figure 1. Both indices reflect returns derived from traditional core real estate categories including office, apartments, retail, industrial and hotels. Additionally, REITs own specialty property types such as self storage and senior housing, while these categories are excluded form NCREIF. Both indices are widely used and regarded as representative of their asset category. A more detailed discussion of the properties of the indices is found in a 2003 article by Joe Gyourko[1].

[1] http://xwhartonrealestate.merchantquest.net/research/papers/full/470.pdf

3 Returns

In the following charts, we look at the comparative returns of NAREIT and NCREIF indices. REITs are typically levered at 1 to 1.5 to one, while NCREIF is an unlevered index. In order to make the returns more comparable and relevant to the ASRS real estate strategy which contemplates 1 to 1 (50%) leverage, we also provide a 1 to 1 levered NCREIF return. First, we present rolling one year and ten year returns in figure 2.

Adjusted for leverage, the NCREIF and NAREIT returns are roughly comparable. We explore this further in the charts in figure 3. In these charts, we plot the difference between the one year rolling and 10 year rolling NAREIT and levered NCREIF returns. We add a regression line to show the trend of the difference. In both cases, the regression line trends down. REITs had a period of strong outperformance during the 1990s. Both indices were much smaller in that time frame with the REIT index holding less than $6 billion in assets in 1990. It's possible that REITs outperformed during the 1990's because they were pursuing more productive parts of the market, but it's also possible that it is simply statistical anomaly. As both indices have become much larger, they appear to have converged. If you look at the later years of the 10 year rolling returns, the NAREIT returns are similar to the levered NCREIF and, by coincidence, nearly identical in the last 10 year period measured.

Figure 2: Rolling Returns

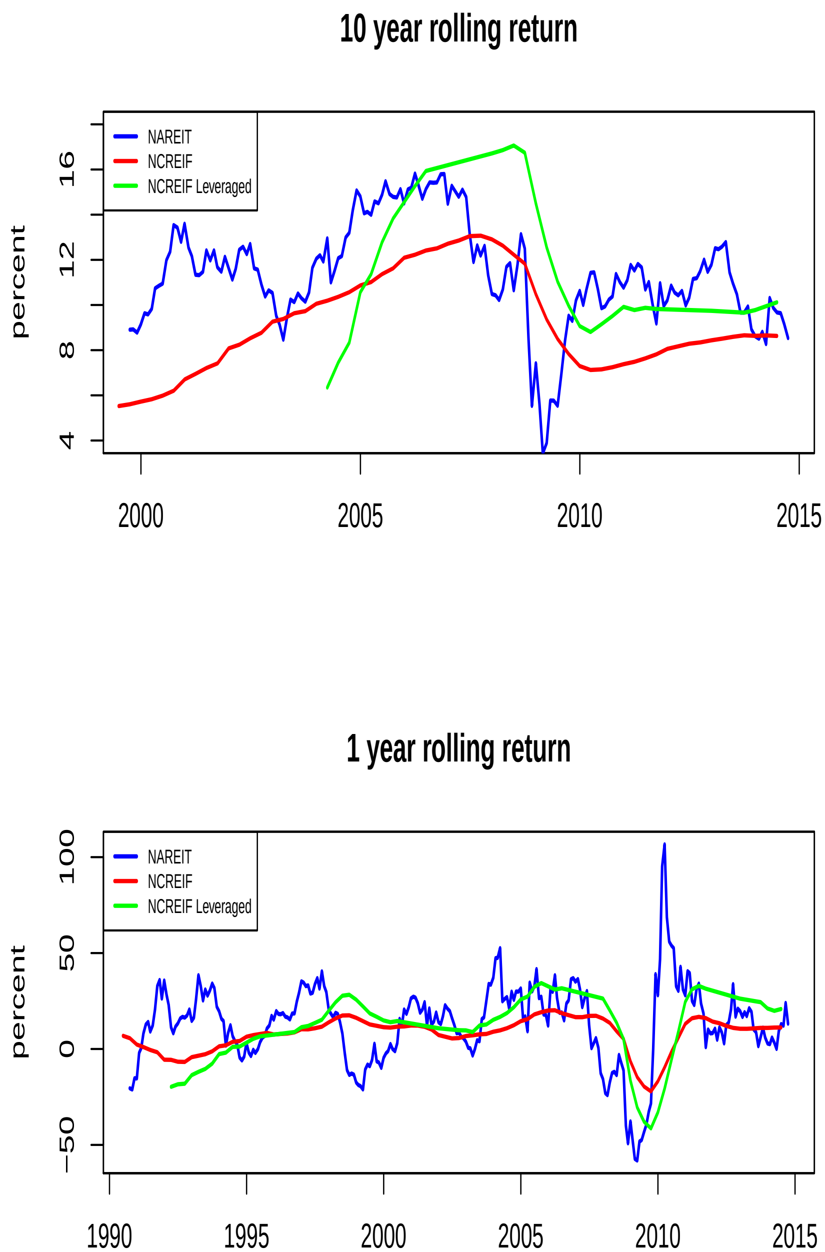
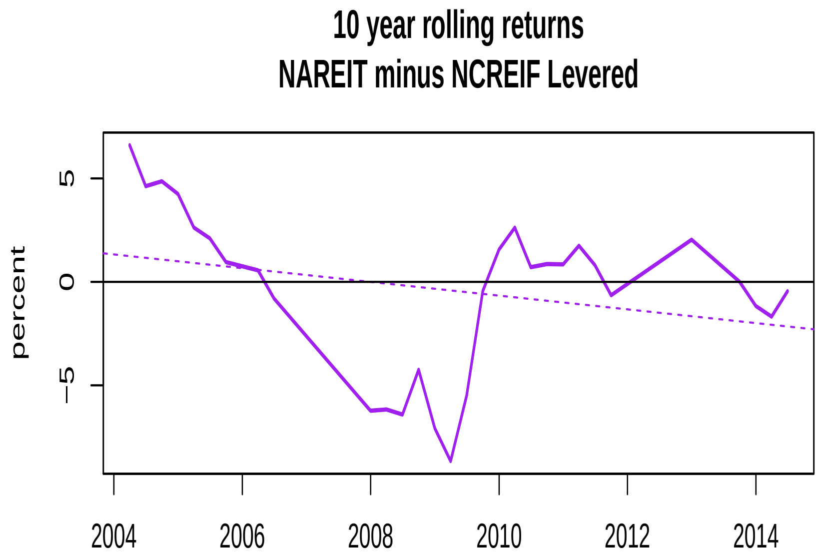


Figure 3: Difference in Returns



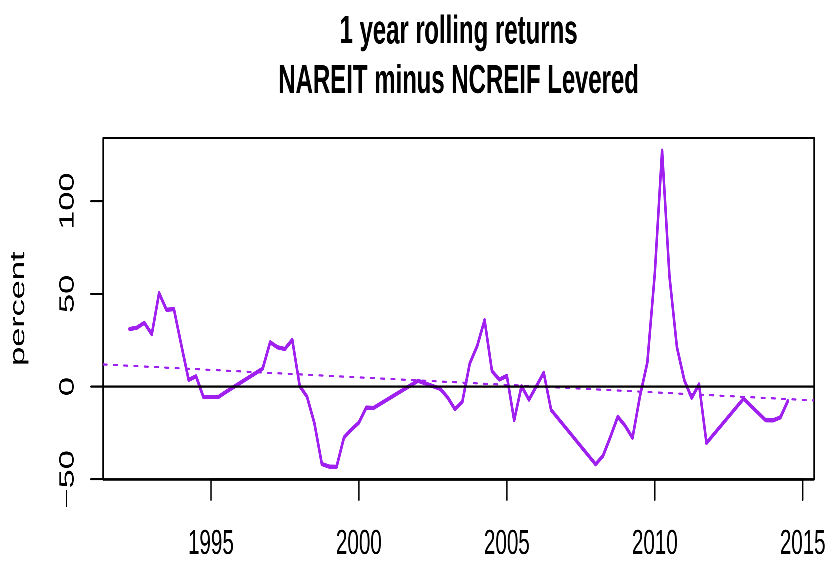
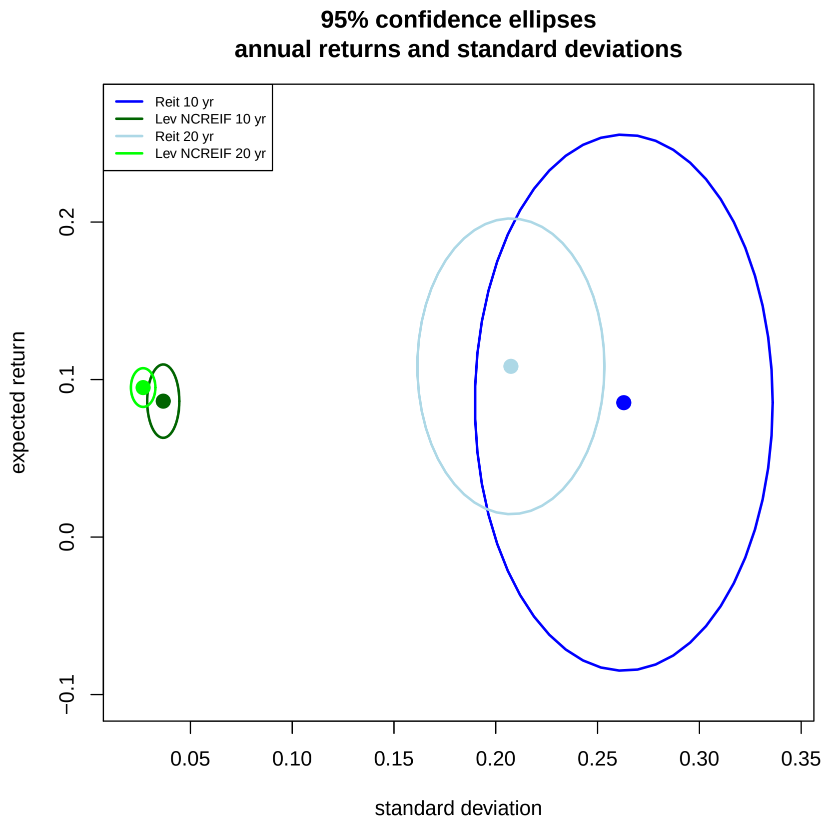


Figure 4: Return and Standard Deviations



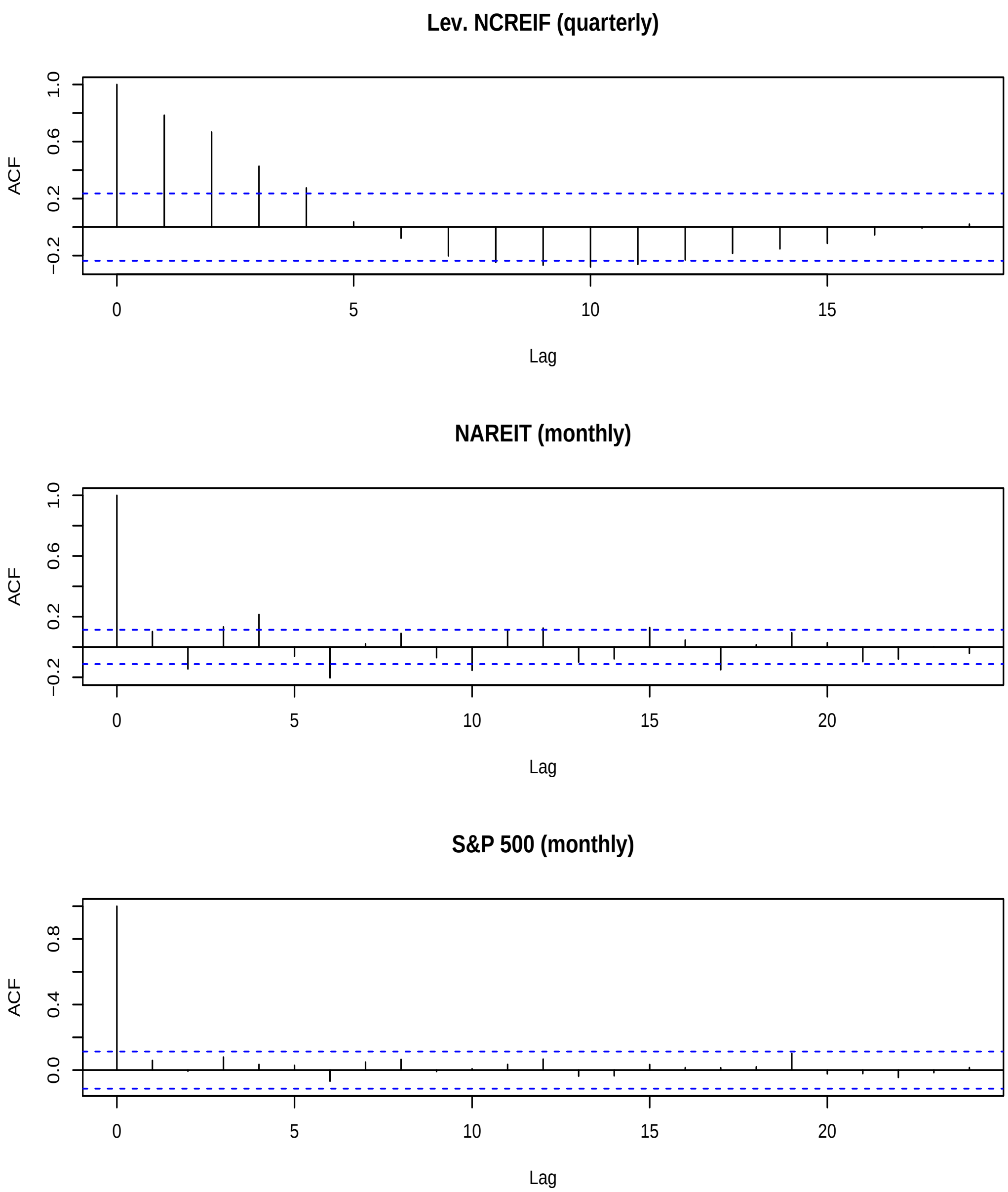
4 Volatility

In figure 4, we present two-sigma confidence ellipses for the return and standard deviation for levered NCREIF and NAREIT for the the most recent 10 and 20 years, ending September 30 for REITs and June 30 for NCREIF. These calculations are based on bootstrapping from those return series over the indicated time frame. While the analysis shows that any difference in returns is not statistically significant, the standard deviation for REITs is much higher.

NCREIF returns are less volatile due to appraisal smoothing. While there is doubt about the usefulness of measured volatility of NCREIF for portfolio construction purposes and we will discuss this below, the appraisal values and returns are required to be used in financial reporting for investors like ASRS.

As you can see in figure 5, NCREIF returns are significantly auto-correlated, while REIT figures are only slightly so. As a reference point, we also plot the autocorrelation of the S&P 500 to show it is not autocorrelated at all.

Figure 5: Autocorrelation



The existence of the autocorrelation is a strong indication of lags from the appraisal process. There has been much discussion of this. Gyourko and Keim in a paper from 1993[2] explore this in depth. A result of the appraisal lags is to significantly smooth the returns and understate their volatility. David Geltner in a paper from the same year[3] discussed a method for desmoothing returns which we illustrate here. This approach assumes that appraisals reflect a blending of information from prior valuations and current market trends such that:

$$R.observed_t = \alpha(R.observed_{t-1}) + (1-\alpha)R.true_t$$

You then solve for the "true" return as follows:

$$R.true_t = (R.observed_t - \alpha(R.observed_{t-1}))/(1-\alpha)$$

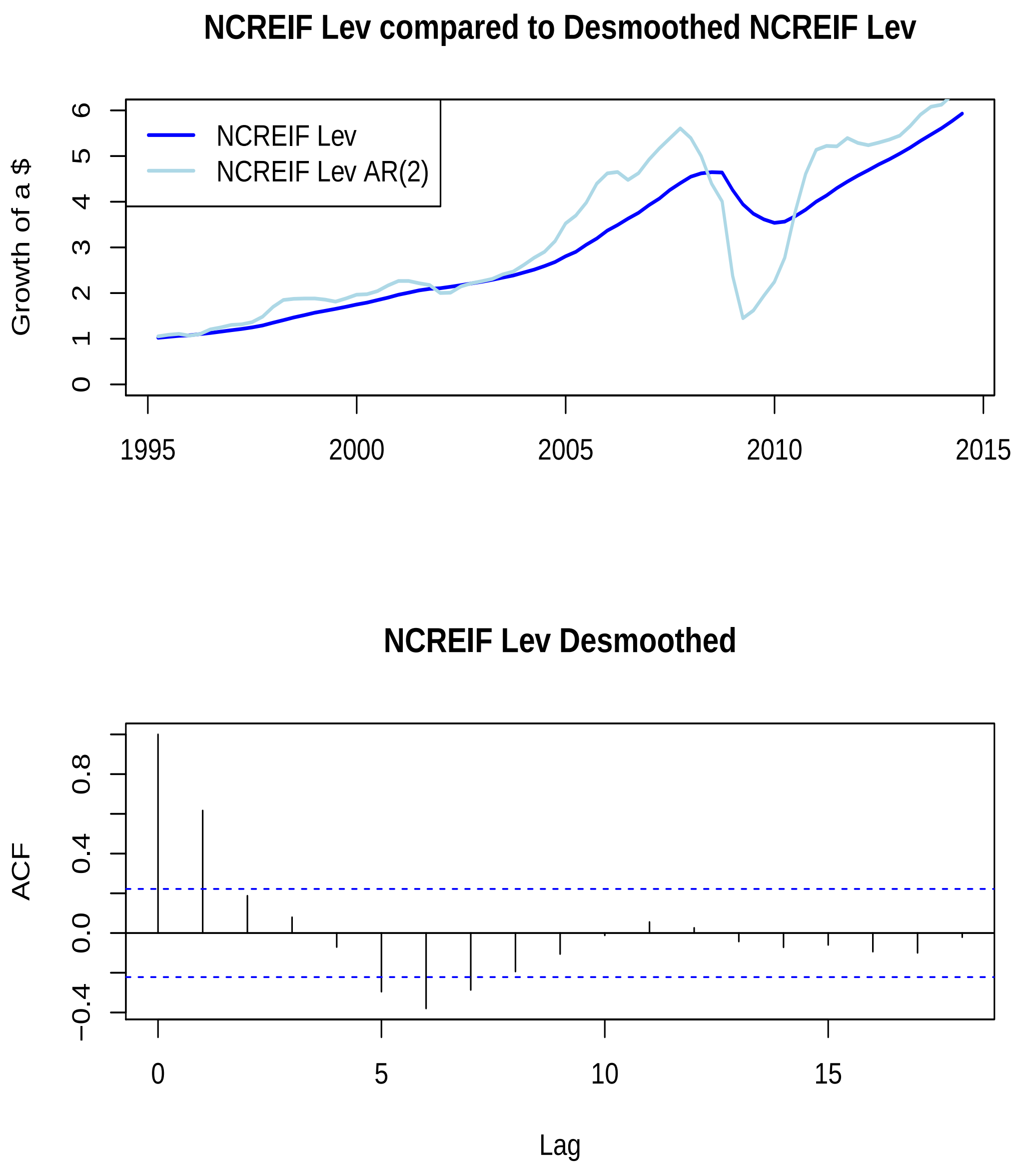
This can be done with one lag term (as shown in the above formulas) or more. You then solve for smoothing parameters with a regression to find the best fit. With one lag term this is called an "AR(1)" process. We have implemented an AR(2) process. The results of the desmoothed returns are shown in figure 6.

The desmoothed data look promising. They show more volatility and the drawdown of around 60% during the GFC is comparable to the drawdown in REITs in the same time frame. The volatility of the desmoothed returns is more than tripled with the desmoothing process. They are still somewhat autocorrelated, but not as bad.

[2] Joseph Gyourko, Donald Keim (1993), What Does the Stock Market Tell Us About Real Estate Returns. AREUEA Journal. Available at this link https://real-estate.wharton.upenn.edu/files/?whdmsaction=public:main.file&fileID=7141

[3] David Geltner, Estimating Market Values from Appraised Values Without Assuming an Efficient Market. Journal of Real Estate Research 8(3), 325-345

Figure 6: Desmoothed Returns



5 Correlation

Understanding the correlation of real estate with liquid assets is a conundrum and estimates vary widely. The researchers mentioned above have shown that with some statistical coaxing REITs and NCREIF respond to economic conditions similarly and, when adjusted for leverage, generate comparable returns. That makes sense because it is the exact same activity with a different legal wrapper. That's helpful, but we have more work to do to understand how real estate behaves in a portfolio with other assets.

If we check the correlation of daily REIT returns with S&P 500 returns over the last 5 years, we find that REITs are 83% correlated with large cap stocks. When you consider that the S&P 500 is nearly 50% in tech, pharma and financial firms which bear little resemblance to rental real estate, this is surprising. If we do the same calculation with monthly data since 1994, we still get a correlation of 58%. Clearly the stock market has a big influence on REIT valuation, especially in shorter time frames.

On the other hand, if we check the levered NCREIF correlations using monthly data over the same time period, NCREIF is only 15% correlated with the stock market. This is surprisingly low. Notwithstanding big differences in the fundamental nature of the businesses, both share a connection to the economy and depressed aggregate demand will negatively impact either activity. Desmoothing appears to be of some help here. In addition to increasing volatility to plausible levels the correlation to the stock is increased to 25%, which still feels low but is moving in the right direction.

In tables 1 and 2, we show the mean returns, standard deviation and correlation matrix for these series using monthly returns for 20 years ended June 30, 2014.

	Assumed Rtrn	Calculated Rtrn	Assumed SD	Calculated SD
REIT	8.00	10.90	20.00	20.70
Lev. NCREIF	8.00	9.50	3.00	2.70
Lev NCREIF AR(2)	8.00	10.20	15.00	12.50
SP500	9.00	9.80	15.00	15.30
LehmAGG	5.00	6.20	4.00	3.60

Table 1: Returns and Standard Deviation

	REIT	Lev. NCREIF	Lev NCREIF AR(2)	SP500	LehmAGG
REIT	100.00	19.60	40.80	57.50	14.40
Lev. NCREIF	19.60	100.00	57.70	14.80	-5.40
Lev NCREIF AR(2)	40.80	57.70	100.00	25.00	3.30
SP500	57.50	14.80	25.00	100.00	1.70
LehmAGG	14.40	-5.40	3.30	1.70	100.00

Table 2: Correlation Matrix

6 Efficient Portfolios

We will calculate efficient portfolios using the data in the return and correlation tables above. We are using a standard mean-variance optimization algorithm to find a minimum volatility portfolio with an expected return of 8% per year.

In our first cut at these calculations, we will use the calculated values for the standard deviation and correlation matrix but will use the "assumed returns" shown in table 1. We believe that the true underlying returns of real estate are the same whether owned in a public REIT or a private structure. Any difference in measured returns reflects market or statistical anomaly, not a fundamental property that should be incorporated in a portfolio modeling framework. Similarly, we set the return for "desmoothed" NCREIF equal to the other real estate categories. We believe 8% is a reasonable long term expected return for levered real estate. We set stock returns 100bp higher at 9%. We set bond returns at 5%. The last 20 years have seen falling rates which have increased bond returns. In a flat to rising rate environment, bond returns should be lower than what occurred in the past 20 years.

We present in figure 7 three efficient portfolios. Each of the portfolios selects among three assets. Stocks and bonds are included in all the portfolios. The third asset is one of the three real estate constructs – NAREIT, levered NCREIF, or levered NCREIF desmoothed by the AR(2) process. The MVO model does not give any weight to NAREIT – it is correlated with stocks, has higher volatility and lower returns. The model loves levered NCREIF and assigns nearly 100% of assets to this category – it has very low volatiliy, low correlation and good returns. But we have doubts about the reliability of the NCREIF numbers for portfolio allocation purposes because the appraisal process causes volatility and correlations to be understated. Finally, we present a portfolio built using desmoothed NCREIF data reflecting higher volatility and higher correlation to the other assets. This portfolio allocates about 15% to bonds and splits the rest between stocks and real estate. Some real world portfolios might look like that, but the weight is still quite high and much higher than commercial real estate is represented as a proportion among all invest-able assets.

As a thought experiment, we decided to attempt to reverse engineer capital markets. If real estate is 10% to 20% of invest-able assets, what sort of parameters would be consistent in an MVO context for an allocation to real estate of around 20%. We experimented with increased volatility and found that as long as real estate was less volatile, the model tended to approximately split the non-bond assets between stocks and real estate. We also experimented with correlation and found much the same outcome. It wasn't until we increased volatility to an amount equal to what is assumed for stocks and increased correlation to 50% (almost as high as REITs) that the model would reduce its allocation to real estate to around 20%.

Figure 7: Efficient Portfolios

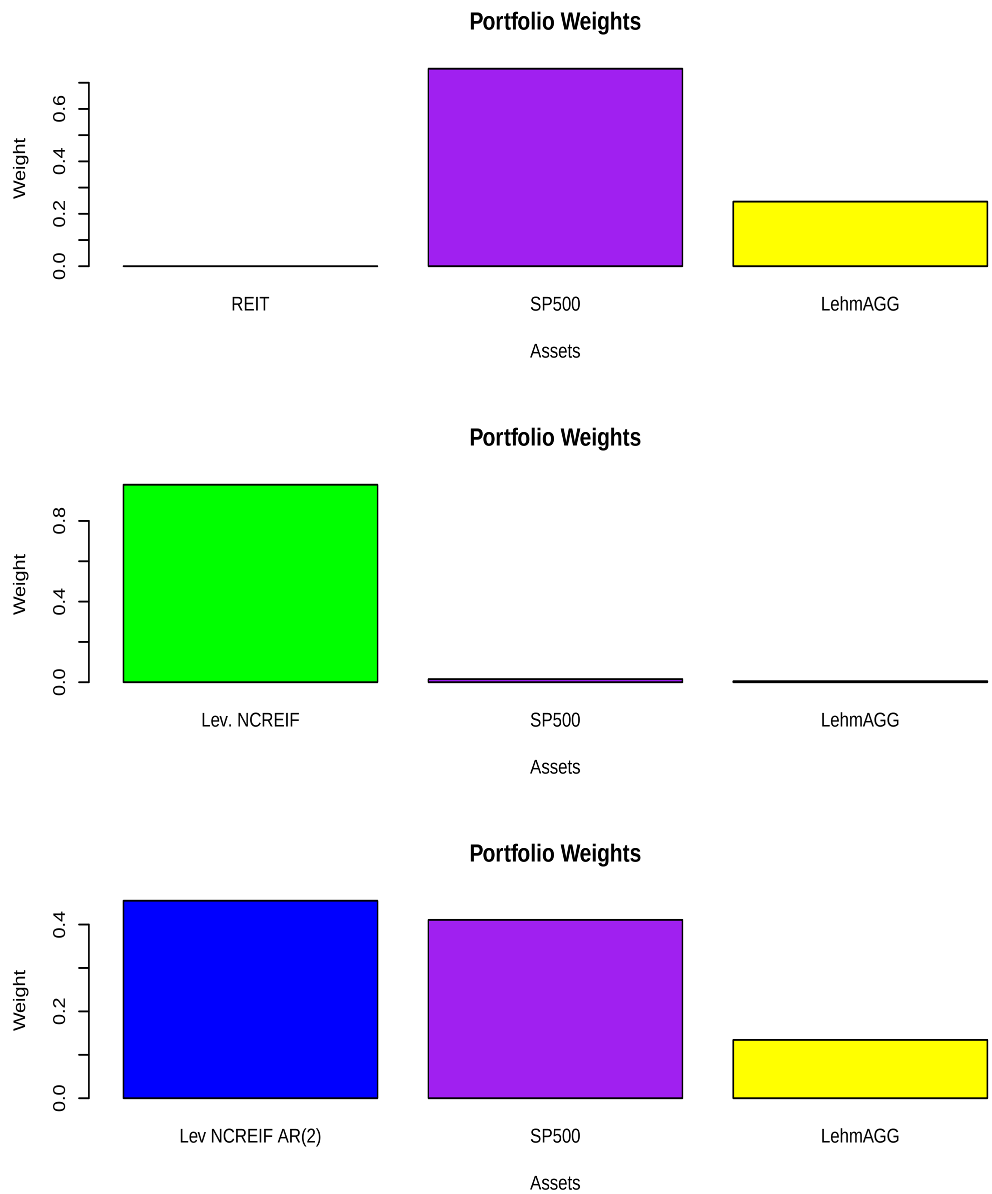
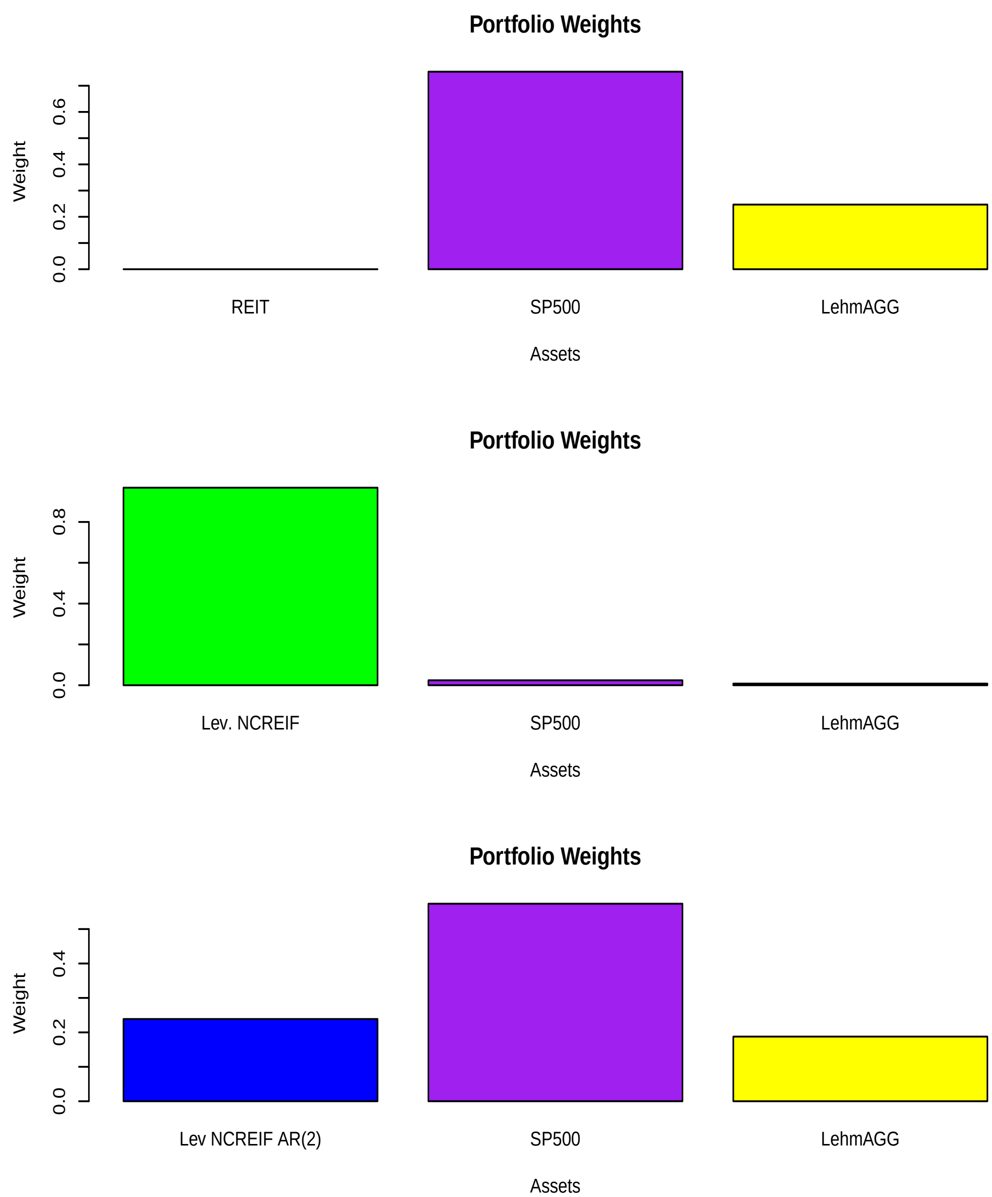


Figure 8: Efficient Portfolios with Assumed Standard Deviations and 50% correlation of NCREIF AR(2) to SP500



7 Conclusions

REITs and NCREIF are indices reflecting returns from ownership of real estate. When adjusted for leverage, there returns are statistically equivalent although one form of ownership may outperform the other for certain stretches of time. The most reasonable conclusion is that their expected returns are the same.

REITs are very volatile. They are much more volatile than private real estate and more volatile than the stock market. The volatility of private real estate is underestimated by the NCREIF data which is autocorrelated and suffers from smoothing as a result of the appraisal process. Statistical methods of desmoothing have been studied and are illustrated here. The "true" volatility is likely much higher than what is measured from NCREIF data.

REITs are highly correlated to the stock market, in the 80s on daily data and in the 50s on monthly data. NCREIF shows very low correlation to other assets, but this is likely understated because of appraisal smoothing. Statistically desmoothed NCREIF series show increaed correlation to both stock and REITs.

We calculated standard deviations and correlations for real estate as NAREIT, levered NCREIF and desmoothed levered NCREIF. Standard MVO models do not select NAREIT and grab large portions of unfiltered NCREIF. These results are moderated when using desmoothed NCREIF but the MVO still selects a large allocation to real estate. We found that if we (arbitrarily) assume that NCREIF volatility is equal to the stock market and 50% correlated with it, the portfolio allocation is reduced to around 20% which is roughly in line with the percentage of commercial real estate among all invest-able assets.

REITs are real estate and an acceptable way to gain exposure to real estate if you are indifferent to volatility and correlation to the stock market. They have the advantage of liquidity but are not expected to generate a higher return. REITs move with the stock market, especially in the short run and thus provide less diversification benefit than private real estate. While the "true" volatility of private real estate is likely to be much higher than the reported volatility based on appraisals, such valuation is used in financial reporting for investors like ASRS and some people regard that as a benefit.

In a future writing, we will discuss active management and tactical approaches with REITs.

8 Code and Data

8.1 Link to files

Code and data for this project are found on the ASRS server at the following link P:\IMD\Karl\R projects\reits

8.2 Code for data analysis, graphs and tables

```
#
# calcs and graphs for the reit 1.lyx file
#
## @knitr setup
# initial setup and data retrieval
#
require (zoo, quietly=TRUE)
require (boot, quietly=TRUE)
require (car, quietly=TRUE)
source('../basic_financial.r')
load("reitdata.rdata")
#
## @knitr marketcap
#
# market cap of REIT index copmared to NCREIF
#
require(zoo, quietly=TRUE)
eqreitmarketcap=c(5.5,8.8,11.1,26.1,38.8,49.9,
                  78.3,127.8,126.9,118.2,134.4,
                  147.1,151.3,204.8,275.3,301,
                  400,289,176,248,359,407,544,608)
eqreitmarketcap=zooreg(eqreitmarketcap, start=1990)
ncreifmarketcap=zoo(c(38,49,95,145,329),
                    c(1990,1995,2000,2004,2013))
plot(eqreitmarketcap, col='blue', lwd=2,
     xlab="", ylab="$ Billions")
lines(ncreifmarketcap, col='red', lwd=2)
legend('topleft',
       legend=c("NAREIT Index","NCREIF NPI"),
       col=c('blue','red'), lwd=2)
#
## @knitr rolling
#
# rolling returns
#
require(zoo, quietly=TRUE)
mu.ncreif.lev=(2*(mu.ncreif-(.5*.25*(zoneyr+.0175))))
```

```r
ncreif.10yr=4*rollapply(mu.ncreif,
                        40,mean,align='right')
ncreif.10yr.lev=4*rollapply(mu.ncreif.lev,
                        40,mean,align='right')
reit.10yr=12*rollapply(mu.reit,
                        120,mean,align='right')
ncreif.10yr.geo=-1+exp(ncreif.10yr)
ncreif.10yr.lev.geo=-1+exp(ncreif.10yr.lev)
reit.10yr.geo=-1+exp(reit.10yr)
par(mfrow=c(2,1))
plot(100*reit.10yr.geo,col='blue',
     xlab="",ylab="percent",lwd=2,
     main="10 year rolling return",
     ylim=c(4,18))
lines(100*ncreif.10yr.geo,col='red',lwd=2)
lines(100*ncreif.10yr.lev.geo,col='green',lwd=2)
legend("topleft",legend=c("NAREIT","NCREIF","NCREIF 
   Leveraged"),
       col=c("blue","red","green"),lwd=2,cex=.6)
ncreif.1yr=4*rollapply(mu.ncreif,
                        4,mean,align='right')
ncreif.1yr.geo=-1+exp(ncreif.1yr)
ncreif.1yr.lev=4*rollapply(mu.ncreif.lev,
                        4,mean,align='right')
ncreif.1yr.lev.geo=-1+exp(ncreif.1yr.lev)
reit.1yr=12*rollapply(mu.reit,
                        12,mean,align='right')
reit.1yr.geo=-1+exp(reit.1yr)
plot(100*reit.1yr.geo,col='blue',lwd=2,
     main="1 year rolling return",
     xlab="",ylab="percent")
lines(100*ncreif.1yr.geo,col='red',lwd=2)
lines(100*ncreif.1yr.lev.geo,col='green',lwd=2)
legend("topleft",legend=c("NAREIT","NCREIF","NCREIF 
   Leveraged"),
       col=c("blue","red","green"),lwd=2,cex=.6)
#
## @knitr diff
#
# plot difference between rolling returns
# and show regression line
#
require(zoo,quietly=TRUE)
par(mfrow=c(2,1))
diff.10yr=reit.10yr.geo-ncreif.10yr.lev.geo
plot(100*diff.10yr,col='purple',lwd=2,
```

```
      xlab="",ylab='percent',
      main="10 year rolling returns\nNAREIT minus NCREIF 
         Levered")

abline(lm(100*diff.10yr~time(diff.10yr)),lty='dashed',col
   ='purple')
abline(h=0)
diff.1yr=reit.1yr.geo-ncreif.1yr.lev.geo
plot(100*diff.1yr,col='purple',lwd=2,
      xlab='',ylab='percent',
      main="1 year rolling returns\nNAREIT minus NCREIF 
         Levered")
abline(lm(100*diff.1yr~time(diff.1yr)),lty='dashed',col='
   purple')
abline(h=0)
#
# plot confidence ellipses of returns and standard
   deviations
#
## @knitr ellipse
require(zoo,quietly=TRUE)
cormatdaily=cor(merge(mu.spxt.daily,mu.reit.daily),
                use="pairwise.complete.obs")
mu.reit.m=zooreg(coredata(mu.reit)[-(1:57)],
                 start=as.yearmon(time(mu.reit[58])),
                 freq=12)
mu.spxt.m=zooreg(coredata(mu.spxt)[-(1:57)],
                 start=as.yearmon(time(mu.spxt[58])),
                 freq=12)
mu.ncreif.m1=mu.ncreif[time(mu.ncreif)>=as.Date(time(mu.
   reit.m)[1])]
mun=coredata(mu.ncreif.m1)/3
ncreifmat=rbind(mun,mun,mun)
mu.ncreif.m=as.vector(ncreifmat)
mu.ncreif.m=zooreg(mu.ncreif.m,start=time(mu.reit.m)[1],
   freq=12)
mureit=coredata(mu.reit.m)[-(1:3)]
mu.reit.m=mu.reit.m[time(mu.reit.m)<=time(mu.ncreif.m)[
   length(mu.ncreif.m)]]
mu.spxt.m=mu.spxt.m[time(mu.spxt.m)<=time(mu.ncreif.m)[
   length(mu.ncreif.m)]]
muncreif=coredata(mu.ncreif.m)
mu.rr=data.frame(mureit,muncreif)
# bootstrap returns and standard deviations
br=function(r,d) {
  c(12*mean((r[d])),sqrt(12)*sd((r[d])))
```

```
}
set.seed(1532)
colors=c("blue","dark green","light blue","green")
par(mfrow=c(1,1))
reit.b10=boot::boot(coredata(tail(mu.reit.m,120)),br,R
    =999)
ncreif.b10=boot::boot(coredata(tail(mu.ncreif.m,120)),br,
    R=999)
reit.b20=boot::boot(coredata(tail(mu.reit.m,240)),br,R
    =999)
ncreif.b20=boot::boot(coredata(tail(mu.ncreif.m,240)),br,
    R=999)
# plot 95% confidence ellipse of expected return and
    standard deviation
nr=(nrow(mu.rr)-119):nrow(mu.rr)
muhat.vals10 = -1+exp(12*colMeans(mu.rr[nr,]))
sigmahat.vals10 = sqrt(12)*apply(mu.rr[nr,],2,sd)
nr=(nrow(mu.rr)-239):nrow(mu.rr)
muhat.vals20 = -1+exp(12*colMeans(mu.rr[nr,]))
sigmahat.vals20 = sqrt(12)*apply(mu.rr[nr,],2,sd)
muhat.vals=c(muhat.vals10,muhat.vals20)
sigmahat.vals=c(sigmahat.vals10,sigmahat.vals20)
se.muhat = c(sd(reit.b10$t[,1]),sd(ncreif.b10$t[,1]),
             sd(reit.b20$t[,1]),sd(ncreif.b20$t[,1]))
se.sigmahat = c(sd(reit.b10$t[,2]),sd(ncreif.b10$t[,2]),
                sd(reit.b20$t[,2]),sd(ncreif.b20$t[,2]))
mu.lower = muhat.vals - 2.2*se.muhat
mu.upper = muhat.vals + 2.2*se.muhat
sigma.lower = sigmahat.vals - 2.2*se.sigmahat
sigma.upper = sigmahat.vals + 2.2*se.sigmahat
plot(sigmahat.vals, muhat.vals, xlim=c(min(sigma.lower),
    max(sigma.upper)),
      ylim=c(min(mu.lower),max(mu.upper)), xlab="standard
          deviation",ylab="expected return",
      main="95% confidence ellipses\nannual returns and
          standard deviations")
mm=2*2*matrix(c(1,0,0,1),nrow=2,ncol=2)
for (i in 1:length(muhat.vals)) {
  car::ellipse(c(sigmahat.vals[i],muhat.vals[i]),
               mm, c(se.sigmahat[i],se.muhat[i]),col=
                   colors[i])
}
names=c("Reit 10 yr","Lev NCREIF 10 yr","Reit 20 yr","Lev
    NCREIF 20 yr")
legend("topleft",names, col=colors,lwd=2,cex=.7)
#
```

```
# plot the autocorrelation charts
#
## @knitr autocor
require(zoo, quietly=TRUE)
par(mfrow=c(3,1))
acf(coredata(mu.ncreif.lev),main="Lev. NCREIF (quarterly)
  ")
acf(coredata(mu.reit),main="NAREIT (monthly)")
acf(coredata(mu.spxt),main="S&P 500 (monthly)")
#
# calculate and plot the desmoothed returns
#
## @knitr desmooth
par(mfrow=c(2,1))
order=2
mun=coredata(mu.ncreif.m1)
ncf.ar=ar(mun,aic=FALSE,order.max=order,method="ols")
ncf.mod=rep(NA,order)
for (i in (1+order):length(mun)) ncf.mod[i]=(mun[i+-(
  order:1)]%*%ncf.ar$ar)
ncf.desm=(mun-ncf.mod)/(1-sum(ncf.ar$ar))
ncf.desm=zoo(ncf.desm,time(mu.ncreif.m1))
plot(exp(cumsum(mu.ncreif.m1[-(1:order)])),col='blue',lwd
  =2,
    main="NCREIF Lev compared to Desmoothed NCREIF Lev",
    xlab='',ylab="Growth of a $",
    ylim=c(0,6))
gd.desm=exp(cumsum(ncf.desm[-(1:order)]))
lines(gd.desm,col='light blue',lwd=2)
legend('topleft',
       legend=c("NCREIF Lev","NCREIF Lev AR(2)"),
       col=c("blue","light blue"),lwd=2)
acf(coredata(ncf.desm)[-(1:order)],main="NCREIF Lev 
  Desmoothed")
# uncomment the next three lines to see drawdown charts
#require(fBasics)
#drawdownPlot(as.timeSeries(coredata(ncf.desm)))
#drawdownPlot(as.timeSeries(coredata(mu.reit.m)))
ndesm=coredata(ncf.desm)/3
ndesmat=rbind(ndesm,ndesm,ndesm)
mu.ncd.m=as.vector(ndesmat)
mu.ncd.m=zooreg(mu.ncd.m,start=time(mu.reit.m)[1],freq
  =12)
#
# calculate and print tables of returns, standard
  deviations and correlation matrix
```

```
#
## @knitr coremat
require(xtable, quietly=TRUE)
require(zoo, quietly=TRUE)
mu.agg1=mu.agg[as.yearmon(time(mu.agg))>=time(mu.reit.m)
    [1]]
mu.agg1=mu.agg1[as.yearmon(time(mu.agg1))<=tail(time(mu.
    reit.m),1)]
mu.agg.m=zooreg(coredata(mu.agg1),start=time(mu.reit.m)
    [1], freq=12)
mumat=merge(mu.reit.m,mu.ncreif.m,mu.ncd.m,mu.spxt.m,mu.
    agg.m)
corematmonthly=cor(mumat,
                   use='pairwise.complete.obs')
corematm=corematmonthly
corematmonthly=round(100*corematmonthly,1)
names=c("REIT","Lev._NCREIF","Lev_NCREIF_AR(2)","SP500","
    LehmAGG")
colnames(mumat)=names
rownames(corematmonthly)=names
colnames(corematmonthly)=names
muvec=apply(mumat,2,mean,na.rm=TRUE)
muvec=round(100*(-1+exp(12*muvec)),1)
sdvec=apply(mumat,2,sd,na.rm=TRUE)
sdvec=round(100*sdvec*sqrt(12),1)
assumed=c(8,8,8,9,5)
assumedsd=c(20,3,15,15,4)
musdmat=cbind(assumed,muvec,assumedsd,sdvec)
rownames(musdmat)=names
colnames(musdmat)=c("Assumed_Rtrn","Calculated_Rtrn","
    Assumed_SD", "Calculated_SD")
musdmat.x=xtable(as.data.frame(musdmat),caption="Returns_
    and_Standard_Deviation")
print(musdmat.x,scalebox=.8)
coremat.x=xtable(as.data.frame(corematmonthly),caption="
    Correlation_Matrix")
print(coremat.x,scalebox=.8)
#
# calculate and graph the first group of efficient
    portfolios of real estate
# stocks and bonds
#
## @knitr efficient
#
source('portfolio_noshorts.r.txt', encoding='UTF-8')
par(mfrow=c(3,1))
```

```r
omitlist=list(c(-2,-3),c(-1,-3),c(-1,-2))
for (i in 1:length(omitlist)) {
  omit=omitlist[[i]]
  mu.rr=mumat[,omit]#merge(mu.ncd.m,mu.spxt.m,mu.agg.m)
  hasna=apply(is.na(mu.rr),1,any)
  mu.rr=mu.rr[!hasna,]
  cov.mat=var(mu.rr)
  #muhat.vals=apply(mu.rr,2,mean)
  #muhat.vals=assumed[omit]
  muhat.vals=log(1+assumed*.01)/12
  names(muhat.vals)=colnames(mumat)
  tr=(log(1.08))/12
  eff.port=efficient.portfolio(muhat.vals[omit],cov.mat,
      tr,shorts=FALSE)
  #summary(eff.port)
  colors=c("red","green","blue","purple","yellow")
  plot(eff.port,col=colors[omit])
}
#
# calculate and the second set of efficient portfolios
#
## @knitr efficient2
par(mfrow=c(3,1))
omitlist=list(c(-2,-3),c(-1,-3),c(-1,-2))
corematm[4,3]=.5
corematm[3,4]=.5
assumedsd1=.01*assumedsd/sqrt(12)
covmatadj=corematm*outer(assumedsd1,assumedsd1)
for (i in 1:length(omitlist)) {
  omit=omitlist[[i]]
  mu.rr=mumat[,omit]#merge(mu.ncd.m,mu.spxt.m,mu.agg.m)
  hasna=apply(is.na(mu.rr),1,any)
  mu.rr=mu.rr[!hasna,]
  #cov.mat=var(mu.rr)
  #muhat.vals=apply(mu.rr,2,mean)
  #muhat.vals=assumed[omit]
  cov.mat=covmatadj[omit,omit]
  muhat.vals=log(1+assumed*.01)/12
  names(muhat.vals)=colnames(mumat)
  tr=(log(1.08))/12
  eff.port=efficient.portfolio(muhat.vals[omit],cov.mat,
      tr,shorts=FALSE)
  #summary(eff.port)
  colors=c("red","green","blue","purple","yellow")
  plot(eff.port,col=colors[omit])
}
```

```
# some other charts and analysis that I didn't end up using in the presentation
# attempts a different approach to portfolio construction by smoothing the public
# assets instead of desmoothing the private ones
## @knitr smoothedgraph
gdreit=exp(cumsum(mu.reit.m))
gdreit.roll=rollapply(gdreit,18,mean,align='right')
plot(gdreit,col='blue')
lines(gdreit.roll,col='green')
gdreit.2000=gdreit[time(gdreit)>2004]
gdreit.2000=gdreit.2000/coredata(gdreit.2000[1])
gdreit.roll.2000=gdreit.roll[time(gdreit.roll)>2004]
gdreit.roll.2000=gdreit.roll.2000/coredata(gdreit.roll.2000[1])
ncreif.2000=exp(cumsum(mu.ncreif.m[time(mu.ncreif.m)>2004]))
ncreif.2000=ncreif.2000/coredata(ncreif.2000[1])
par(mfrow=c(1,1))
plot(gdreit.2000,col='blue')
lines(gdreit.roll.2000,col='red')
lines(ncreif.2000,col='green')
## @knitr smoothcor
smooth.reit=diff(log(gdreit.roll))
rets=merge(smooth.reit,mu.ncreif.m,mu.spxt.m)
corematsmooth=cor(rets,use='pairwise.complete.obs')
cori=vector()
lags=2:30
for (i in 1:length(lags)) {
  gdreit.rolli=rollapply(gdreit,lags[i],mean,align='right')
  smooth.reiti=diff(log(gdreit.rolli))
  rets=merge(smooth.reiti,mu.ncreif.m)
  coremati=cor(rets,use='pairwise.complete.obs')
  cori[i]=coremati[2,1]
}
plot(lags,cori)
```

8.3 Code for data retrieval

```
#
# capture and prep data from tickers
#
require (Rbbg)
require (zoo)
require (lubridate)
require (XLConnect)
setwd("P:/IMD/Karl/R_projects/reits")
# first get Bloomberg tickers
# RETRANAT Index -- average cap rate U.S. national
# FNERTR Index -- nareit total return
# SPXT Index -- S&P Total Return Index
# CPI YOY Index -- CPI All urban consumers
# USGG5YR Index -- 5 yr treasury yield
# NPPITR Index -- NCREIF total return
conn=blpConnect()
#get daily REIT and SPX for last 5 years
reit.daily=bdh(conn,"FNERTR Index","PX_LAST",Sys.Date()-5
    *366)
spxt.daily=bdh(conn,"SPXT Index","PX_LAST",Sys.Date()-5*
    366)
zreit.daily=zoo(reit.daily$PX_LAST,as.Date(reit.daily$
    date))
zspxt.daily=zoo(spxt.daily$PX_LAST,as.Date(spxt.daily$
    date))
mu.reit.daily=diff(log(zreit.daily))
mu.spxt.daily=diff(log(zspxt.daily))
#get monthly on all for last 25 years
caprates=bdh(conn,"RETRANAT Index","PX_LAST",Sys.Date()
    -25*366,
                option_names="periodicitySelection",option_
                    value="MONTHLY")
zcaprates=.01*zoo(caprates$PX_LAST,as.Date(caprates$date)
    )
cpi=bdh(conn,"CPI YOY Index","PX_LAST",Sys.Date()-25*366,
                option_names="periodicitySelection",option_
                    value="MONTHLY")
zcpi=.01*zoo(cpi$PX_LAST,as.Date(cpi$date))
ncreif=bdh(conn,"NPPITR Index","PX_LAST",Sys.Date()-25*
    366,
          option_names="periodicitySelection",option_value=
              "QUARTERLY")
zncreif=.01*zoo(ncreif$PX_LAST,as.Date(ncreif$date))
mu.ncreif=log(1+zncreif)
```

```
fiveyr=bdh(conn,"USGG5YR Index","PX_LAST",Sys.Date()-25*
    366,
          option_names="periodicitySelection",option_value=
              "MONTHLY")
zfiveyr=.01*zoo(fiveyr$PX_LAST,as.Date(fiveyr$date))
oneyr=bdh(conn,"US0012M Index","PX_LAST",Sys.Date()-25*
    366,
            option_names="periodicitySelection",option_
                value="MONTHLY")
zoneyr=.01*zoo(oneyr$PX_LAST,as.Date(oneyr$date))
reit=bdh(conn,"FNERTR Index","PX_LAST",Sys.Date()-25*366,
           option_names="periodicitySelection",option_value
              ="MONTHLY")
zreit=zoo(reit$PX_LAST,as.Date(reit$date))
mu.reit=diff(log(zreit))
spxt=bdh(conn,"SPXT Index","PX_LAST",Sys.Date()-25*366,
           option_names="periodicitySelection",option_value
              ="MONTHLY")
zspxt=zoo(spxt$PX_LAST,as.Date(spxt$date))
mu.spxt=diff(log(zspxt))
#get lehmann agg from excel file
data=loadWorkbook("Performance Measurement SP.xlsm")
aggval=readWorksheet(data,sheet="Index_Returns",region="
    W9:W472",header=FALSE)
aggdate=readWorksheet(data,sheet="Index_Returns",region="
    A9:A472",header=FALSE)
zagg=zoo(aggval$Col1,aggdate$Col1)
mu.agg=log(1+.01*zagg)
#don't forget to disconnect
blpDisconnect(conn)
save.image("reitdata.rdata")
```