THE CASE OF SIMULATING THE CHOICES OF MONEY MANGERS BY APPLYING MODERN PORTFOLIO THEORY USING REAL STOCK PRICE DATA

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ABSTRACT

Time constraints, as well as ignorance of other business disciplines, often preclude instructors from properly incorporating illustrations from outside their area of expertise into their courses. This can result in students having difficulty in applying skills learned in one course to other courses. We address this student learning issue by showing how the skills and concepts students are learning in an introductory Excel spreadsheet class can be applied to modern portfolio theory using real data from Yahoo! Finance without mathematical and statistical complexity. By using a finance illustration in an information systems course, students are better able to understand the value of the skills they are acquiring now and how these skills will help them solve real-life problems. Moreover, business students who subsequently take an introductory finance course will be familiar with one of finance's most important theories.

INTRODUCTION

Many business students have difficulty applying knowledge learned in one class to other classes, especially if the class is not in their major discipline. Professors often hear statements like the following from students, "I'm a finance major, why do I need to know something about information systems." For these students there is a no connection of how the concepts and skills learned in one class can help them solve problems in another class. In 2002 the Association of American

Colleges and Universities published a report entitled *Greater Expectations: A New Vision for Learning as a Nation Goes to College* that addresses this student learning issue. The report states the following "Once enrolled in College, students face … barriers to excellence. The fragmentation of the curriculum into a collection of independently "owned" courses is itself an impediment to student accomplishment, because the different courses students take, even on the same campus, are not expected to engage or build on one another. Few maps exist to help students plan or integrate their learning as they move in and out of separately organized courses, programs, and campuses. In the absence of shared learning goals and clear expectations, a college degree more frequently certifies completion of disconnected fragments than of a coherent plan for student accomplishment." The Association of Advance Collegiate Schools of Business (AACSB International) expresses similar student learning concerns in their 2003 *Eligibility Procedures and Standards for Business Accreditation*. This AACSB publication promotes cross-functional integration within business programs. We address this student learning issue by showing how students can apply finance's modern portfolio theory using real data in an introductory Excel spreadsheet class.

1990 Nobel Prize winner in economics, Harry Markowitz (1952), is credited with developing modern portfolio theory. His work shows that the adage "don't put all your eggs in one basket" is sound advice. In financial terms he shows that it is possible for investors to combine financial assets (stocks) in such a way that it increases their return while also decreasing their risk. We show that students taking an introductory Excel spreadsheet course can apply his work using real stock price data from Yahoo! Finance. By using a finance application in an information systems class, students will understand how the skills and concepts they are learning in an introductory Excel spreadsheet course can help them in other classes that are often taken years later. It also introduces students to the risk-return trade-off in finance that investment and introductory finance courses cover in detail. Moreover, a number of finance textbooks use Excel to solve and illustrate problems.[iii] Finally, there are a growing number of financial modeling courses at universities and a growing number of financial modeling textbooks that use Excel extensively.[iv]

The purpose of this paper is to show students how simple Excel functions that they commonly learn in an introductory Excel spreadsheet class can help them understand modern portfolio theory without mathematical and statistical complexity. Having students simulate the process of portfolio construction will help them better understand the decision process that money managers use in making their asset allocation decisions. Using Excel's *solver* and *scenario manager* students can

perform a risk-return analysis in little time by developing an efficient frontier and capital market line.[v] First, Excel's *solver* is a tool that optimizes a dependent (output) variable by changing the values of independent (input) variable(s) subject to some constraint(s). *Solver* finds a new solution to the problem each time you change the value of the dependent variable or the value of a constraint. The *solver* function is a part of Excel's *Solver* add-in. If this function is not currently available under the *Tools* menu, it can be installed by loading the *Solver* add-in. To do this, go to the *Tools* menu and click *Add-ins*. In the *Add-Ins* available list, select the *Solver* box, and then click *OK*. Second, *scenario manager* is a tool that can store the solutions from *solver*. Moreover, it provides a convenient way to summarize the solutions that *solver* produces. In addition to *solver* and *scenario manager*, students will learn about naming cells and/or ranges, absolute and relative cell referencing, basic functions such as *average*, *stdev*, and *correl*, *paste special* with several optional features, and *array* formulas.

DOWNLOADING DATA AND COMPUTING RETURNS

To get free historical stock price data go to the following link http://finance.yahoo.com/. This is the home page for Yahoo! Finance. In the *Market Summary* section there are a number of stock indices listed, click on *Dow* and a new page will appear. On this page go to the *More On* section, click on *components*. This page contains an alphabetical listing of the 30 firms that comprise the Dow Jones Industrial Index with their ticker symbols.[vi] As of December 14, 2005, Alcoa Inc. (symbol: AA) was the first firm. The screen should look similar to figure 1.

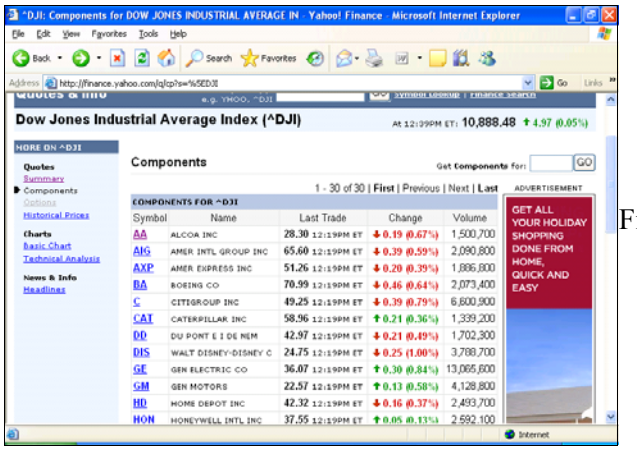
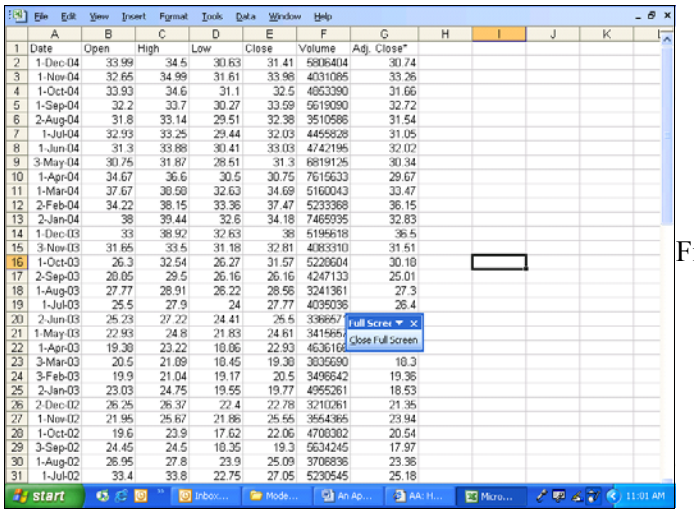


Figure 1

Clicking on the first ticker symbol, *AA*, opens AA's Yahoo! Finance home page. In the section *More on AA* click on *historical prices*. In the set date range select *monthly*. In the *start date* select *December 31, 2001*. In the *end date* select *December 31, 2004*. Now click on *Get Prices*. Scroll down the page and select *Download to Spreadsheet*. Click on *Save* and in this case the ticker symbol is AA so name the file *AA*. By default the file will be saved as comma separated with the file extension *.csv*. Now select *Open* and an Excel worksheet that looks like figure 2 will appear.

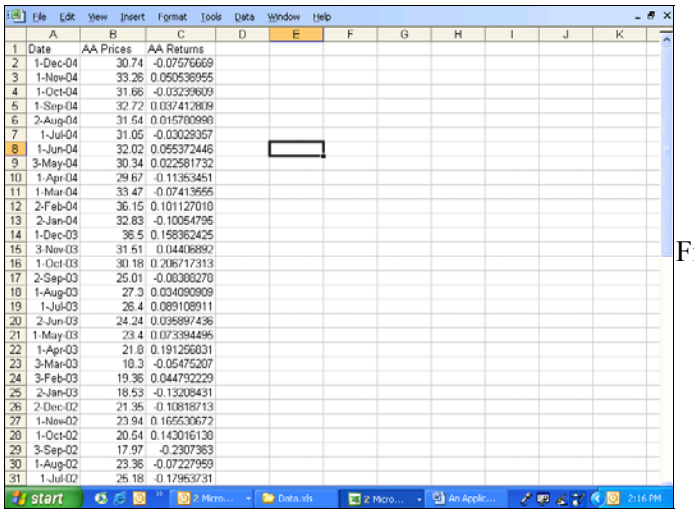


	Date	Open	High	Low	Close	Volume	Adj. Close*
2	1-Dec-04	33.99	34.5	30.63	31.41	5806404	30.74
3	1-Nov-04	32.65	34.99	31.61	33.98	4031085	33.26
4	1-Oct-04	33.93	34.6	31.1	32.5	4853390	31.66
5	1-Sep-04	32.2	33.7	30.27	33.59	5619090	32.72
6	2-Aug-04	31.8	33.14	29.51	32.38	3510586	31.54
7	1-Jul-04	32.93	33.25	29.44	32.03	4455828	31.05
8	1-Jun-04	31.3	33.88	30.41	33.03	4742195	32.02
9	3-May-04	30.75	31.87	28.51	31.3	6819125	30.34
10	1-Apr-04	34.67	36.6	30.5	30.75	7615633	29.67
11	1-Mar-04	37.67	38.58	32.63	34.69	5160043	33.47
12	2-Feb-04	34.22	38.15	33.36	37.47	5233368	36.15
13	2-Jan-04	38	39.44	32.6	34.18	7465935	32.83
14	1-Dec-03	33	38.92	32.63	38	5195618	36.5
15	3-Nov-03	31.65	33.5	31.18	32.81	4083310	31.51
16	1-Oct-03	26.3	32.54	26.27	31.57	5220604	30.18
17	2-Sep-03	28.05	29.5	26.16	26.16	4247133	25.01
18	1-Aug-03	27.77	28.91	26.22	28.56	3241361	27.3
19	1-Jul-03	25.5	27.9	24	27.77	4035036	26.4
20	2-Jun-03	25.23	27.22	24.41	25.5	336857	
21	1-May-03	22.93	24.8	21.83	24.61	341665	
22	1-Apr-03	19.38	23.22	18.86	22.93	4636166	
23	3-Mar-03	20.5	21.09	18.45	19.38	3835690	18.3
24	3-Feb-03	19.9	21.04	19.17	20.5	3496642	19.36
25	2-Jan-03	23.03	24.75	19.55	19.77	4965261	18.53
26	2-Dec-02	26.25	26.37	22.4	22.78	3210261	21.35
27	1-Nov-02	21.95	25.67	21.86	25.55	3564365	23.94
28	1-Oct-02	19.6	23.9	17.62	22.06	4700302	20.54
29	3-Sep-02	24.45	24.5	18.35	19.3	5634245	17.97
30	1-Aug-02	26.95	27.8	23.9	25.09	3708836	23.36
31	1-Jul-02	33.4	33.8	22.75	27.05	5230545	25.18

Figure 2

Now select columns B:F by hovering the mouse over column B and holding down the left mouse button while moving the mouse over to column F. Release the left mouse button and delete these columns by right clicking the mouse and selecting *delete*. Next, in cell B1 enter *AA Prices* and in cell C1 enter *AA returns*.

To compute monthly stock price changes in decimals for AA select cell *C2* and enter the formula *=B2/B3-1*. Copy this formula down to cell *C37* by selecting cell *C2* and hovering the pointer over the lower right corner of cell C2 until it turns into a black plus sign. Hold down the left mouse button and drag to cell *C37*, then release. To save your file go to *File>Save As*. In the *file name enter AA* and in the *Save as Type* select *Microsoft Excel Workbook* by scrolling up. The saved file will look like figure 3.



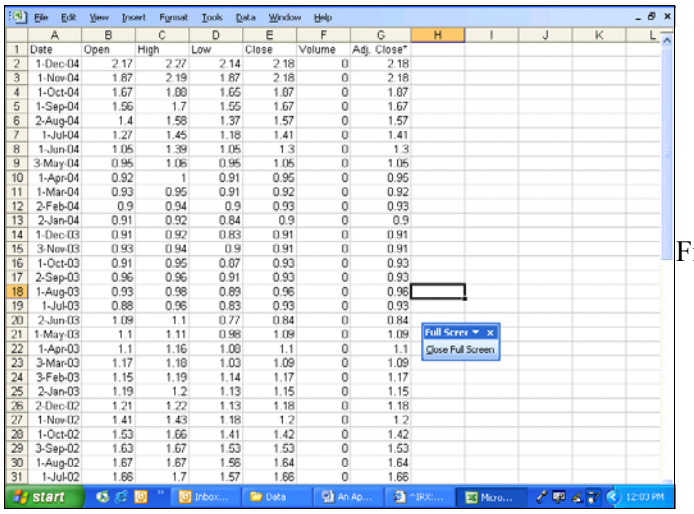
	A	B	C
1	Date	AA Prices	AA Returns
2	1-Dec-04	30.74	-0.07576669
3	1-Nov-04	33.26	0.050536955
4	1-Oct-04	31.66	-0.03239609
5	1-Sep-04	32.72	0.037412809
6	2-Aug-04	31.54	0.015760990
7	1-Jul-04	31.05	-0.03029357
8	1-Jun-04	32.02	0.055372446
9	3-May-04	30.34	0.022581732
10	1-Apr-04	29.67	-0.11353451
11	1-Mar-04	33.47	-0.07413655
12	2-Feb-04	36.15	0.101127010
13	2-Jan-04	32.83	-0.10054795
14	1-Dec-03	36.5	0.158362425
15	3-Nov-03	31.51	0.04406892
16	1-Oct-03	30.18	0.206717313
17	2-Sep-03	25.01	-0.08388278
18	1-Aug-03	27.3	0.034090909
19	1-Jul-03	26.4	0.089108911
20	2-Jun-03	24.24	0.035897436
21	1-May-03	23.4	0.073394495
22	1-Apr-03	21.8	0.191256831
23	3-Mar-03	18.3	-0.05475207
24	3-Feb-03	19.36	0.044792229
25	2-Jan-03	18.53	-0.13208431
26	2-Dec-02	21.35	-0.10818713
27	1-Nov-02	23.94	0.165530672
28	1-Oct-02	20.54	0.143016130
29	3-Sep-02	17.97	-0.2307363
30	1-Aug-02	23.36	-0.07227959
31	1-Jul-02	25.18	-0.17953731

Figure 3

Repeat this process for the remaining 29 stocks left in the Dow index. Remember to use the appropriate ticker symbols to name the files and for naming price and return columns within each file. To help organize the files it is probably best to create two new folders. One folder will contain *.csv* files with price data downloaded from Yahoo! Finance and the other folder will contain *.xls* files that have just dates, prices, and computed monthly stock returns.

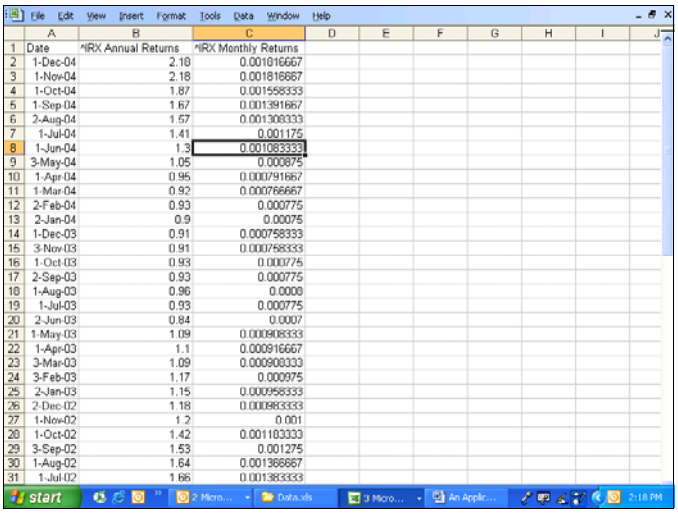
Finally, to get a risk-free rate of return go to http://finance.yahoo.com/, enter *^IRX* in the *Enter Symbol(s)* area and click on *GO*. ^IRX is the ticker symbol for the 13-week U.S. treasury bill. Use the same start dates and end dates as before and name the *.csv* file using the ticker symbol when downloading the information. Now select *Open* and an Excel worksheet that looks like figure 4 will appear.

Delete columns B:F like before. Next, in cell B1 enter *^IRX Annual Returns* and in cell C1 enter *^IRX Monthly Returns*. To compute monthly returns for ^IRX select cell *C2* and enter the formula *=B2/(12*100)*.[vii] *Copy* this formula down to cell *C37*. To save the file go to *File>Save As*. In the *file name* enter *^IRX* and in the *Save as Type* select *Microsoft Excel Workbook* by scrolling up. The saved file will look like figure 5.



	A	B	C	D	E	F	G
1	Date	Open	High	Low	Close	Volume	Adj. Close*
2	1-Dec-04	2.17	2.27	2.14	2.18	0	2.18
3	1-Nov-04	1.87	2.19	1.87	2.18	0	2.18
4	1-Oct-04	1.67	1.88	1.65	1.87	0	1.87
5	1-Sep-04	1.56	1.7	1.55	1.67	0	1.67
6	2-Aug-04	1.4	1.58	1.37	1.57	0	1.57
7	1-Jul-04	1.27	1.45	1.18	1.41	0	1.41
8	1-Jun-04	1.05	1.39	1.05	1.3	0	1.3
9	3-May-04	0.95	1.06	0.95	1.05	0	1.05
10	1-Apr-04	0.92	1	0.91	0.95	0	0.95
11	1-Mar-04	0.93	0.95	0.91	0.92	0	0.92
12	2-Feb-04	0.9	0.94	0.9	0.93	0	0.93
13	2-Jan-04	0.91	0.92	0.84	0.9	0	0.9
14	1-Dec-03	0.91	0.92	0.83	0.91	0	0.91
15	3-Nov-03	0.93	0.94	0.9	0.91	0	0.91
16	1-Oct-03	0.91	0.95	0.87	0.93	0	0.93
17	2-Sep-03	0.96	0.96	0.91	0.93	0	0.93
18	1-Aug-03	0.93	0.98	0.89	0.96	0	0.96
19	1-Jul-03	0.88	0.96	0.83	0.93	0	0.93
20	2-Jun-03	1.09	1.1	0.77	0.84	0	0.84
21	1-May-03	1.1	1.11	0.98	1.09	0	1.09
22	1-Apr-03	1.1	1.16	1.09	1.1	0	1.1
23	3-Mar-03	1.17	1.18	1.03	1.09	0	1.09
24	3-Feb-03	1.15	1.19	1.14	1.17	0	1.17
25	2-Jan-03	1.19	1.2	1.13	1.15	0	1.15
26	2-Dec-02	1.21	1.22	1.13	1.18	0	1.18
27	1-Nov-02	1.41	1.43	1.18	1.2	0	1.2
28	1-Oct-02	1.53	1.66	1.41	1.42	0	1.42
29	3-Sep-02	1.63	1.67	1.53	1.53	0	1.53
30	1-Aug-02	1.67	1.67	1.56	1.64	0	1.64
31	1-Jul-02	1.66	1.7	1.57	1.66	0	1.66

Figure 4



	A	B	C
1	Date	^IRX Annual Returns	^IRX Monthly Returns
2	1-Dec-04	2.18	0.001816667
3	1-Nov-04	2.18	0.001816667
4	1-Oct-04	1.87	0.001558333
5	1-Sep-04	1.67	0.001391667
6	2-Aug-04	1.57	0.001308333
7	1-Jul-04	1.41	0.001175
8	1-Jun-04	1.3	0.001083333
9	3-May-04	1.05	0.000875
10	1-Apr-04	0.95	0.000791667
11	1-Mar-04	0.92	0.000766667
12	2-Feb-04	0.93	0.000775
13	2-Jan-04	0.9	0.00075
14	1-Dec-03	0.91	0.000758333
15	3-Nov-03	0.91	0.000758333
16	1-Oct-03	0.93	0.000775
17	2-Sep-03	0.93	0.000775
18	1-Aug-03	0.96	0.0008
19	1-Jul-03	0.93	0.000775
20	2-Jun-03	0.84	0.0007
21	1-May-03	1.09	0.000908333
22	1-Apr-03	1.1	0.000916667
23	3-Mar-03	1.09	0.000908333
24	3-Feb-03	1.17	0.000975
25	2-Jan-03	1.15	0.000958333
26	2-Dec-02	1.18	0.000983333
27	1-Nov-02	1.2	0.001
28	1-Oct-02	1.42	0.001183333
29	3-Sep-02	1.53	0.001275
30	1-Aug-02	1.64	0.001366667
31	1-Jul-02	1.66	0.001383333

Figure 5

CREATING THE MASTER RETURN FILE

Currently there are 31 Excel files and we need to create one file that contains the returns for all 30 firms in the Dow Jones and the 13-week U.S. treasury security. Start by opening Excel and select *File>Save As*. In the *file name* enter *master* and select *save*. Second, *open* the *AA* file with the *.xls* extension and select column A. *Copy* column A in the AA file to the master file by selecting *Edit>Copy* from the menu bar and then select column A in the master Excel workbook and

paste the column by selecting *Edit>Paste*. Third, *copy* column C in the AA file to the master file by selecting *Edit>Copy* from the menu bar and then select column B in the master Excel workbook and paste the column by selecting *Edit>Paste Special>Values*. Pasting *values* changes the formulas in this cell range to numbers. Fourth, close the AA file by going to the AA file and selecting *File>Close*.

For the remaining *.xls* files containing returns do not repeat the copy process for the dates. However, repeat the copy process for the returns of the other 29 firms and the 13-week U.S. treasury security. For example, open the AIG file and select column C. This is the column that contains the returns for AIG. *Copy* column C in the AIG file to the master file by selecting *Edit>Copy* from the menu bar and then select column C in the master Excel workbook and paste the column by selecting *Edit>Paste Special>Values*. Close the AIG file by going to the AIG file and selecting *File>Close*. Copy the returns of the remaining 28 firms and the 13-week U.S. treasury security. After copying the returns, the master Excel file will look like figure 6.

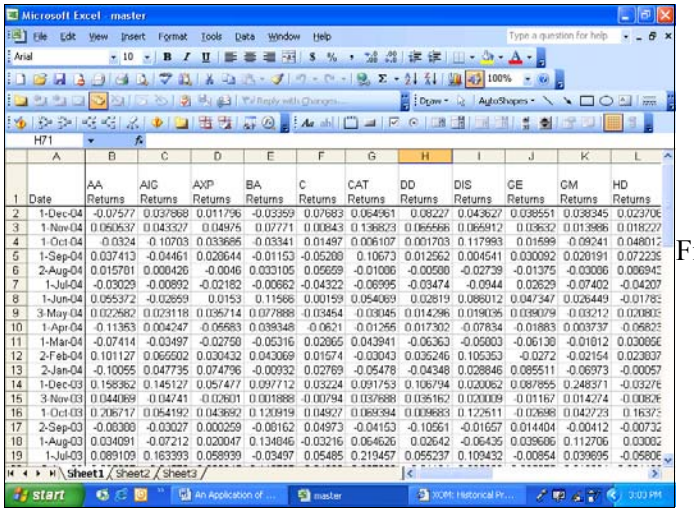


Figure 6

RETURN STATISTICS

To create the efficient frontier and capital market line we need to compute some summary statistics. In cell *A38* type the label *Total Return*, in cell *A39* type the label *Annualized Return*, in cell *A40* type the label *Std Dev of Monthly Returns*, and in cell *A41* type the label *Annualized Std Dev*.[viii] To compute the *total return*,

select cell *B38* and enter *=PRODUCT(1+B2:B37)-1* while holding down the *ctrl* and *shift* buttons on the keyboard. Holding these two buttons down while hitting enter will put brackets *{}* around the formula and this creates an *array formula*. *Copy* this formula across row 38 to cell *AF38.* To compute the *annualized return,* select cell *B39* and enter *=(1+B69)^(1/3)-1*. *Copy* this formula across row 39 to cell *AF39*. To compute the *std dev of monthly returns*, select cell *B40* and type *=stdev(b2:b37).* *Copy* this formula across row 40 to cell *AF40*. Finally, to compute the *annualized std. dev*, select cell *B41* and type *=B40*SQRT(12).* *Copy* this formula across row 41 to cell *AF41*.

To help organize the workbook, *rename Sheet1* by moving the pointer over Sheet1 and right clicking the mouse. A pop-up menu will appear and select *rename*. Rename this worksheet by entering *Returns.* Likewise, rename sheet2 to *Portfolio*.

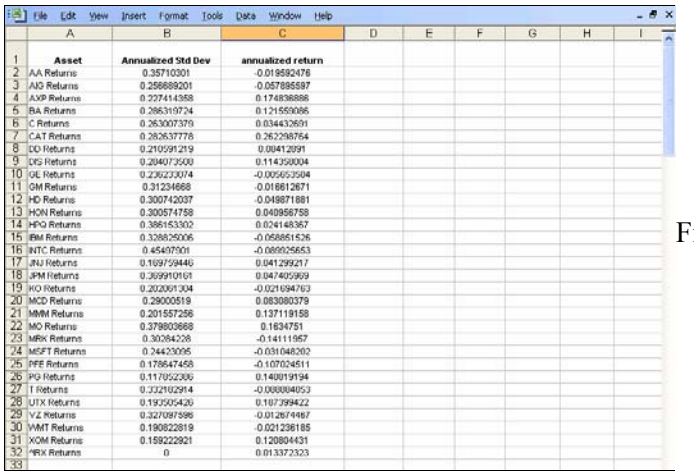
EFFICIENT FRONTIER WORKSHEET-FORMATTING

To create the efficient frontier we need to enter some cell labels on *the Portfolio worksheet* and compute some additional statistics. Much of the work in this section involves moving between the *Returns worksheet* and *Portfolio worksheet*. We begin by entering cell labels on the *Portfolio worksheet* and copying statistics from the *Returns worksheet* to the *Portfolio worksheet*.

Go to the *Portfolio worksheet* and in cell *A1* enter *Asset,* in cell *B1* enter *Annualized Std Dev*, and in cell *C1* enter *Annualized Return*. Now select the *Returns worksheet* and highlight cells *B1:AF1* and select *Edit>Copy*. Go back to the *Portfolio worksheet*, highlight cell *A2* and paste this information by selecting *Edit>Paste Special*. Be sure to *transpose* the cell range and copy *values*. Transposing a row of cells changes it into a column of cells. Repeat this process for the annualized standard deviation and annualized return. For example, go to the *Returns worksheet*, highlight the cell range *B41:AF41*, and select *Edit>Copy*. Return to the *Portfolio worksheet*, select cell *B2* and paste this information by selecting *Edit>Paste Special*. Be sure to *transpose* the cell range and copy *values*. After copying the annualized return information, the *Portfolio worksheet* will look like figure 7.

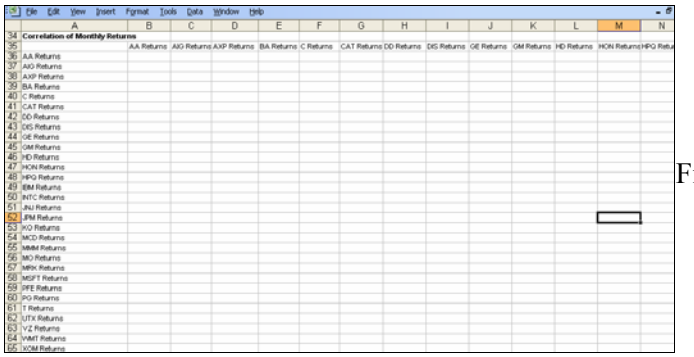
Next, we need to create three matrices on the *Portfolio worksheet*.[ix] The first matrix is for stock return correlations. In cell *A34* enter *Correlation of Monthly Stock Returns*. We first create labels for the 30 stocks in range *A36:A65* by entering a formula *=A2* in cell *A36* and then copy this formula to cell *A65*. Be sure that you don't copy the 13-week treasury bill returns. It is not needed for this matrix. Next,

we paste the labels we just created in the range *A36:A65*, a range aligned in a column, to the range *C35:AE35*, a range aligned in a row. We do this by selecting the range *A36:A65* and then go to *Edit>Copy*. Next, move the cursor to cell *B35*, and then go to *Edit>Paste Special* checking two options: *Values* and *Transpose*. Figure 8 shows the results.



	A	B	C
1	**Asset**	**Annualized Std Dev**	**annualized return**
2	AA Returns	0.35710301	-0.019592476
3	AIG Returns	0.256889201	-0.057895597
4	AXP Returns	0.227414368	0.174836886
5	BA Returns	0.286319724	0.121559086
6	C Returns	0.263007379	0.034432601
7	CAT Returns	0.282637778	0.262298764
8	DD Returns	0.210591219	0.00412091
9	DIS Returns	0.284073500	0.114358004
10	GE Returns	0.236233074	-0.005653504
11	GM Returns	0.31234668	-0.016812671
12	HD Returns	0.300742037	-0.049871881
13	HON Returns	0.300574758	0.040956758
14	HPQ Returns	0.386163302	0.024148367
15	IBM Returns	0.326825006	-0.058851526
16	INTC Returns	0.45497901	-0.089925653
17	JNJ Returns	0.169759446	0.041299217
18	JPM Returns	0.369910161	0.047405969
19	KO Returns	0.202061304	-0.021694763
20	MCD Returns	0.29000519	0.083080379
21	MMM Returns	0.201557256	0.137119158
22	MO Returns	0.379803668	0.1634751
23	MRK Returns	0.30284208	-0.14111957
24	MSFT Returns	0.24423006	-0.031048202
25	PFE Returns	0.178647458	-0.107024511
26	PG Returns	0.117052306	0.140819194
27	T Returns	0.232102914	-0.000884053
28	UTX Returns	0.193505426	0.187399422
29	VZ Returns	0.327087586	-0.012674487
30	WMT Returns	0.190822819	-0.021236185
31	XOM Returns	0.159222921	0.120804431
32	^IRX Returns	0	0.013372323

Figure 7



	A	B	C	D	E	F	G	H	I	J	K	L	M	N
34	**Correlation of Monthly Returns**													
35		AA Returns	AIG Returns	AXP Returns	BA Returns	C Returns	CAT Returns	DD Returns	DIS Returns	GE Returns	GM Returns	HD Returns	HON Returns	HPQ Retu
36	AA Returns													
37	AIG Returns													
38	AXP Returns													
39	BA Returns													
40	C Returns													
41	CAT Returns													
42	DD Returns													
43	DIS Returns													
44	GE Returns													
45	GM Returns													
46	HD Returns													
47	HON Returns													
48	HPQ Returns													
49	IBM Returns													
50	INTC Returns													
51	JNJ Returns													
52	JPM Returns													
53	KO Returns													
54	MCD Returns													
55	MMM Returns													
56	MO Returns													
57	MRK Returns													
58	MSFT Returns													
59	PFE Returns													
60	PG Returns													
61	T Returns													
62	UTX Returns													
63	VZ Returns													
64	WMT Returns													
65	XOM Returns													

Figure 8

The second matrix is for stock return variances and covariances. In cell *A67* enter *Variance-Covariance of Monthly Stock Returns*. Similar to the correlation matrix, two identical sets of labels for the 30 stocks need to be created in range *A69:A98* and range *B68:AE68*, respectively. Note, the 13-week treasury bill data is not needed in this matrix either. Figure 9 shows the results.

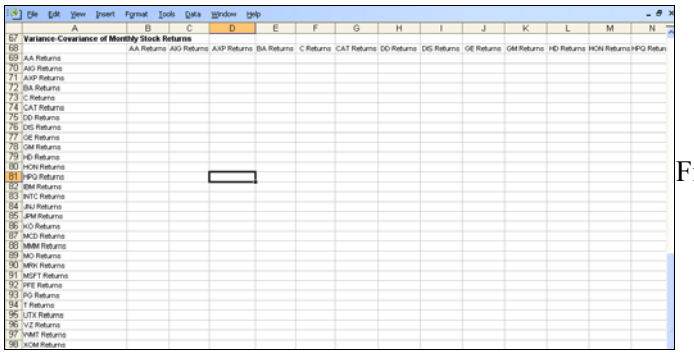


Figure 9

The third matrix is needed to compute statistics for the portfolio of 30 stocks. First create labels for the 30 stocks in ranges *A69:A133* and *C102:AF102*, respectively, using similar techniques. Next, we create weights for each of the 30 stocks in a portfolio. In cell *B103* enter the label *Weight*. In cell *B104* enter *=1/30* and *copy* this formula to cell *B133*. The original portfolio is going to be equally weighted. Since there are 30 stocks in the portfolio, we will invest 1/30 in each stock. To change the for*m*ulas in this cell range to values highlight the cell range *B104:B133,* select *Edit>Copy>Edit>Paste Special,* and select *values*. We need to change the formulas to values so that solver can find solutions in the following section. Next, we need to transpose the weights we just created in range *B04:B133* to range *C103:AF103*. However, this time we use another technique instead of the *Edit>Paste Special* used for the other two matrices. Again, the reason for this is that it is necessary step for solver to find solutions in the next section. The new technique uses the *offset* function in Excel. First, create auxiliary labels 1, 2, 3, through 30, in range *C100:AF100* as follows: in cell *C100* enter 1, in cell *D100* enter 2, then select both cells *C100* and *D100* and hover the pointer over the lower right corner of cell *D100* until it turns into a black plus sign, hold down the left mouse button and drag to cell *AF100*. Next, enter the formula *=offset($B$103,C100,0)* in cell *C103,* and then *copy* the formula to *AF103*. You can check your formulas in the range C103:AF103 by changing a weight in the cell range B104:B133. For example, select cell *B119*. This is the weight for JNJ and it is currently set equal to 0.033333. Change this value by entering *0.10*. Now go to cell *R103* and the value should be *0.10*.

To finish labeling the *Portfolio worksheet* select cell *A134* and enter *Sum of Weights*; *A135*, enter *Portfolio Variance*; *A136*, enter *Portfolio Standard Deviation*; *A137*, enter *Portfolio Return*; and *A138*, enter *Capital Market Line*. Now

that the cell labeling is finished we can proceed to computing statistics for the three matrices. Figure 10 shows the results.

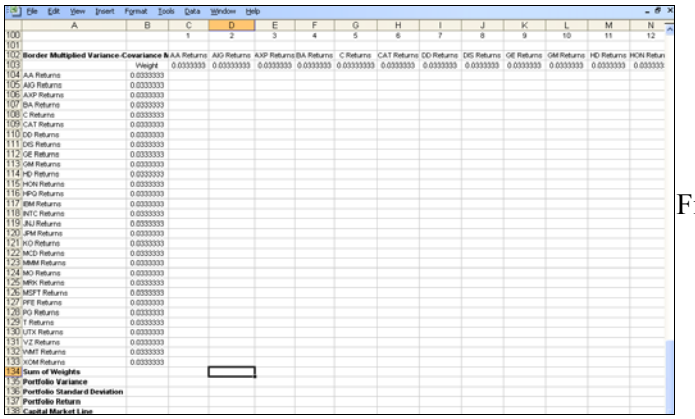


Figure 10

EFFICIENT FRONTIER WORKSHEET-FORMULAS

On the *Portfolio worksheet* select cell *B36* in the correlation matrix. To enter correlations select *Insert>Function*. In the *search for a function* area type *correl,* select *Go*, then *OK*. This brings-up Excel's correlation function, which is named *correl*. Select *Array1* by moving the pointer to the spreadsheet symbol to the right of the text box and right clicking the mouse. Now select the *Returns worksheet*, highlight the cell range *B2:B37* and hit *enter*. The following should appear in the *Array1* text box *Returns!B2:B37*. Next, select *Array2*. Now select the *Returns worksheet*, highlight the cell range *B2:B37*, hit *enter* and click *OK*. This computes the correlation between AA and AA. To increase efficiency change the formula in cell B36 by entering *dollar signs ($)*. To do this, select cell *B36* on the *Portfolio worksheet* and go to the formula. Currently the formula should read =CORREL(Returns!B2:B37,Returns!B2:B37). Change the formula so that it reads *=CORREL(Returns!$B2:$B37,Returns!B2:B37)* and hit *enter*. *Copy* the formula in cell *B36* to the cell range *C36:AE36*. Repeat this process for the remaining cells. For example, select cell *B37* and go to *Insert>Function*. The Correl function should be highlighted under the section *select a function* so click *OK*. If not, repeat the process above. Select *Array1*. Now select the *Returns worksheet*, highlight the cell range *C2:C37* and hit *enter*. The following should appear in the *Array1* text box *Returns!C2:C37*. Next, select *Array2*. Now select the *Returns worksheet*, highlight

the cell range *B2:B37*, hit *enter*, and click *OK*. Currently the formula should read =CORREL(Returns!C2:C37,Returns!B2:B37). Change it so that it reads *=CORREL(Returns!$C2:$C37,Returns!B2:B37)*. *Copy* the formula in cell *B37* to the cell range *C37:AE37*. Repeat this process for the remaining cells.[x] The cell formulas for the correlation matrix are in appendix A.

To enter the variances and covariances go to the *Portfolio worksheet*, select cell *B69*, enter the formula *=B36*B2*$B$2*, and *copy* it down column B to cell *B98*. Next, select cell *C69* on the *Portfolio worksheet*, enter the formula *=C36*B2*$B$3* and *copy* it down column C to cell *C98*. Continue entering formulas in this manner for columns D to AE. In column AE, select cell *AE69*, enter the formula *=AE36*B2*$B$31*, and *copy* it down column AE to cell *AE98*. The cell formulas for the variance-covariance matrix are in appendix B.

The last matrix is the border multiplied variance-covariance matrix. We need to compute values in this matrix so that we can compute the variance and standard deviation for the portfolio. Go to the *Portfolio worksheet*, select cell *C104* and enter *=$B104*C$103*B69*. *Copy* the formula in *C104* to the range *C104:AF133*.

To finish entering formulas into the Portfolio worksheet select cell *B134* and enter *=SUM(B104:B133)*. *Copy* this formula across row 134 to cell *AF134*. The sum of weights should equal 1 in cell B134. Continue computing portfolio statistics by selecting cell *B135* and entering *=SUM(C134:AF134)*. Third, select cell *B136* and enter *=B135^(1/2)*. Fourth, select cell *B137* and enter *=sum(B104:B133*C2:C31)* while holding down the *ctrl* and *shift* buttons. Again, holding these two buttons down while entering a formula will put brackets *{}* around the formula and this creates an *array formula*. Fifth, select cell *B138* and enter *=(B137-C32)/B136*. The cell formulas for the border multiplied variance-covariance matrix are in appendix C.

Finally, we will change the names of some cells. Changing the names of these cells will make it easier to interpret results later on. Go to the *Portfolio worksheet* and select cell *B134*. Just to the left of the formula bar where the formula =SUM(B104:B133) appears is the cell reference *B134*. Select this area, type *weights,* and hit *enter*. The name of this cell is now *weights* instead of B134. Repeat this process for the following cells: name B135 variance, B136 std_dev, B137 return, B138 CML, B32 rf_std, and C32 RF_return.

ORIGINAL PORTFOLIO

The original portfolio is equally weighted and we will save this information for this portfolio by saving it as a *scenario*. To do this go to *Tools>Scenarios* and select *Add.* Name the scenario *original portfolio* and in the *changing cells* text box enter *B104:B133*. Select *OK* and a pop-up menu named *scenario values* will appear. Make sure that all values in these cells are set equal to 0.033333 and select *OK*. The *scenario manager* will now have a new scenario named *original portfolio*. Click *close*.

EFFICIENT FRONTIER

To use solver go to *Tools>Solver*. In the *select target cell* input *$B$135* and in the *Equal to:* click *Min*. Cell B135 is the output (dependent) variable. In the *By Changing Cells* enter *$B$104:$B$133*. The cell range B104:B133 contain the input (independent) variables that solver will change to minimize the variance of the portfolio. Next, we need to add constraints.

To add the constraints, select *Add*. For the first constraint do the following. In the *cell reference* input *$B$134*, select =, and in the *Constraint* input *1.* Click *Add*. For the second constraint, enter *$B$137* in the *cell reference*, select =, and in the C*onstraint* input *-0.10*. Click *OK*. The *solver parameters* will look like figure 11.

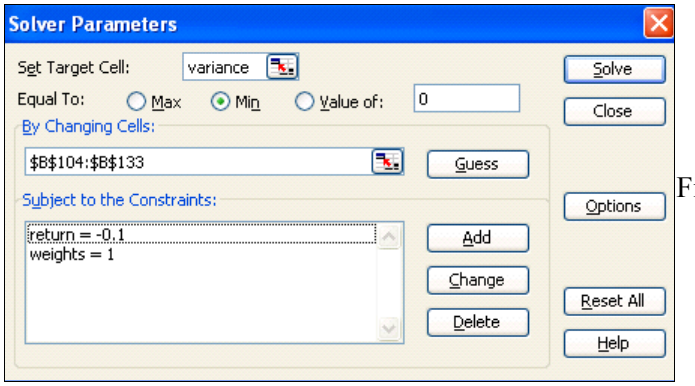


Figure 11

To run solver click *Solve*. If solver successfully finds a solution it will return a screen similar to figure 12.

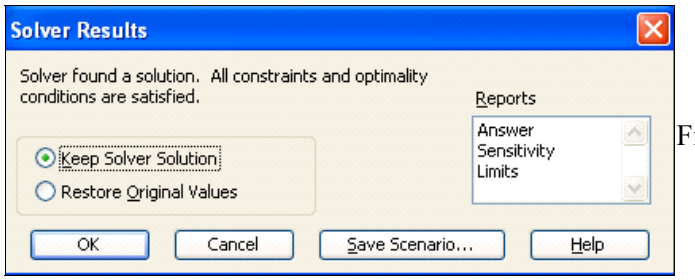


Figure 12

To keep the solution, select *Save Scenario* and name the scenario *r=-10%*. The save scenario screen will look like figure 13.

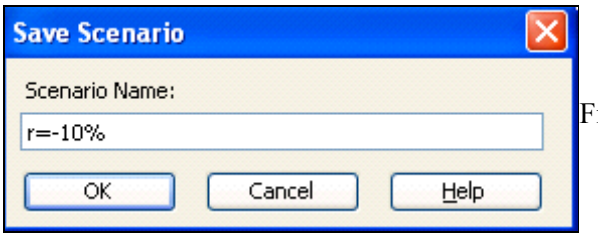


Figure 13

Click *OK*. We have just saved our first *scenario*!

To create more scenarios go to *Tools>Solver* and in the *Subject to the constraints* section select *return=-0.10* and click *Change*. In the *Constraint* section enter a new return value equal to *-0.075* and click *OK*. This will take you back to the *Solver Parameters* screen. Click *Solve*. Solver will find a solution and just like before select *Save Scenario*. Name the scenario *r=-7.5%* and click *OK*. Repeat this process using the following return values: -0.05, -0.025, 0.00, 0.025, 0.05, 0.075, 0.10, 015, 0.20, 0.25, 0.30, 0.325, 0.35, 0.375, 0.40, 0.50, 0.60, 0.70, 0.80, 0.90 and 1.00. We will graph these scenarios later.

CAPITAL MARKET LINE

To create the efficient frontier we specified a return and had solver minimize the portfolio variance by changing the weight invested in each stock. To find the best capital market line we will have solver maximize the trade-off between risk and return. To do this we need to change some inputs in the *solver parameters*. Go to the *Portfolio worksheet* and select *Tools>Solver*. In the *Set Target Cell* section select cell *B138,* and in the *equal to* section select *Max*. Do not change the *By Changing Cells* section. The following should be entered in this section

$B$104:$B$133. Finally, in the *subject to the Constraints* section *delete* the *return*= constraint. The *Solver Parameters* screen will now look like figure 14.

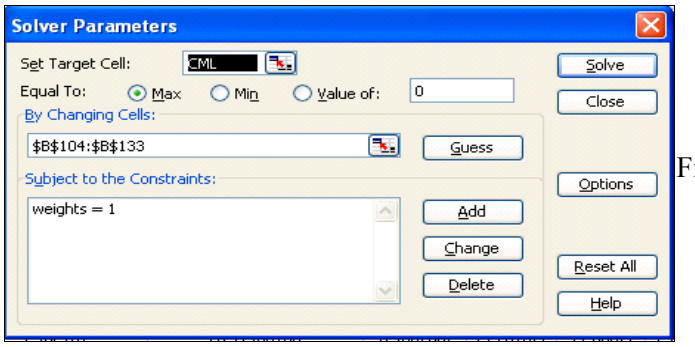


Figure 14

Click *Solve* and select *save scenario*. Name the scenario *MAX CML*.

MINIMUM VARIANCE PORTFOLIO

To compute the minimum variance portfolio select the *Portfolio worksheet* and go to *Tools>Solver*. In the *Set Target Cell* section select cell B135 and in the *equal to* section select *min*. The *Solver Parameters* screen will now look like figure 15.

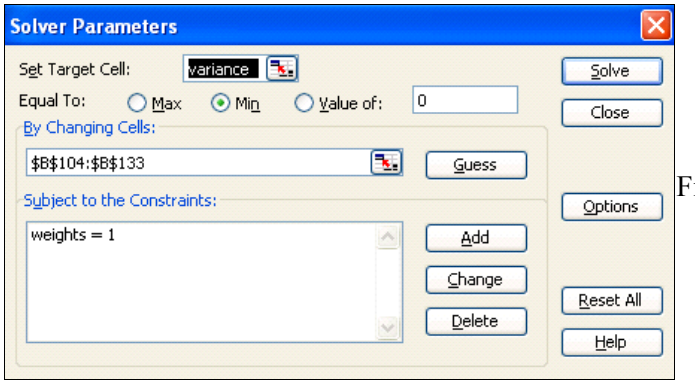


Figure 15

Click *Solve* and select *Save Scenario*. Name the scenario *minimum variance*.

SCENARIO MANAGER

Scenario manager stores all saved scenarios. To access these scenarios go to *Tools>Scenarios* and a screen that looks like figure 16 will appear.

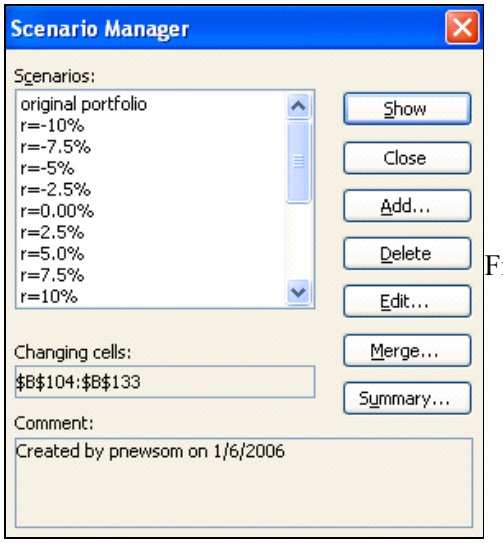


Figure 16

Scrolling down the *Scenarios* section shows additional scenarios including the *MAX CML* and *minimum variance* scenarios. To graph these scenarios *select Summary* and in the *Results cells* input the cell range *B136:B138* and the cell range *B32:C32*. The S*cenario Summary* screen will look like figure 17.

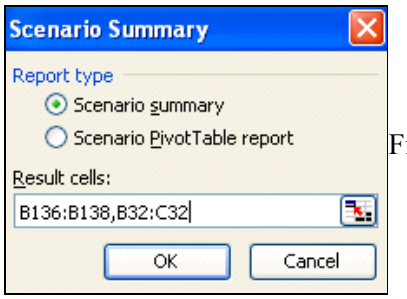
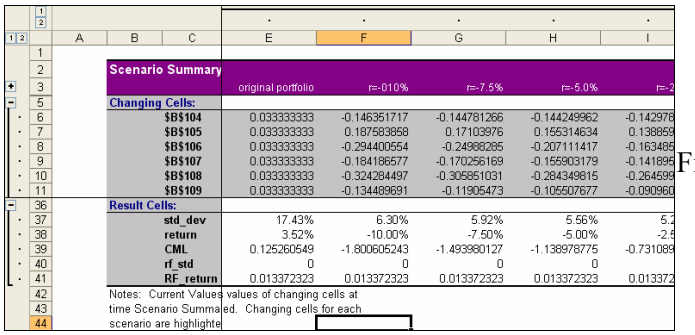


Figure 17

Click *OK* and a new worksheet named *Scenario Summary* that looks like figure 18 will appear. This worksheet contains the information to graph the efficient

frontier, capital market line, original portfolio, and minimum variance portfolio. Positive weights are long positions and negative weights are short positions.[xi]



Scenario Summary						
		original portfolio	r=-010%	r=-7.5%	r=-5.0%	r=-2
Changing Cells:						
	$B$104	0.033333333	-0.146351717	-0.144781266	-0.144249962	-0.142978
	$B$105	0.033333333	0.187583858	0.17103976	0.155314634	0.138859
	$B$106	0.033333333	-0.294400554	-0.24988285	-0.207111417	-0.163485
	$B$107	0.033333333	-0.184186577	-0.170256169	-0.155903179	-0.141895
	$B$108	0.033333333	-0.324284497	-0.305851031	-0.284349815	-0.264599
	$B$109	0.033333333	-0.134489691	-0.11905473	-0.105507677	-0.090960
Result Cells:						
	std_dev	17.43%	6.30%	5.92%	5.56%	5.2
	return	3.52%	-10.00%	-7.50%	-5.00%	-2.5
	CML	0.125260549	-1.800605243	-1.493980127	-1.138978775	-0.731089
	rf_std	0	0	0	0	
	RF_return	0.013372323	0.013372323	0.013372323	0.013372323	0.013372

Notes: Current Values values of changing cells at time Scenario Summaed. Changing cells for each scenario are highlighte

Figure 18

GRAPHING

To graph the *efficient frontier* go to *Insert>Chart*. In the *Chart type* section select *XY (scatter)*. In the *Chart sub-type* section select *Scatter with data points connected by smooth lines*. Click *Next* and select the *Series* tab. In the *series* section click *Remove* until this section is blank. Now click *Add*. Select *X Values*, highlight the cell range *F37:AB37* on the *scenario summary* worksheet and hit *enter*. Next, select *Y Values*, highlight the cell range *F38:AB38* on the *scenario summary* worksheet and hit *enter*. Name the series by entering *Efficient Frontier* in the *Name* section.

To graph the *capital market line* click *Add*. Select *X Values* and while holding down the *CTRL* button, select cell *AC40*, then cell *AC37* on the *Scenario summary* worksheet and hit *enter*. Select *Y Values* and while holding down the *CTRL* button select cell *AC41*, then cell *AC38* on the *Scenario summary* worksheet and hit *enter*. *Name* the series *Capital Market Line*.

To graph the *minimum variance portfolio* click *Add*. Select *X Values*, then select cell *AD37* on the *Scenario summary* worksheet and hit *enter*. Next, select *Y Values*, then select cell *AD38* on the *Scenario summary* worksheet and hit enter. *Name* the series *Minimum Variance Portfolio*.

To graph the *original portfolio* click *Add*. Select *X Values* by selecting cell *E37* on the *Scenario summary* worksheet and hit *enter*. Next, select *Y Values* by selecting cell *E38* on the *Scenario summary* worksheet and hit *enter*. *Name* the series *original portfolio*. Click Next.

Finish the graph by selecting the *Titles* tab. In the *Chart Title* section enter Efficient Frontier, CML, and Min Var Portfolio, in the *Value (x) axis* section enter *Standard Deviation*, and in the *Value (Y) axis* section enter *Return*. Click *Next* and select *as new sheet*. Name the new sheet *Graph* and select *Finish*.

To extend the capital market line left click on the line to highlight it. Now right click and a screen like figure 19 will appear.

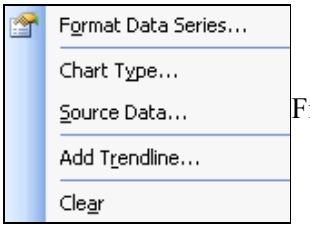


Figure 19

Select *Add Trendline*. Select the *Type* tab and in the *Trend/Regression Type* highlight *Linear*. Now select the *Options* tab. In the *Trendline name* section select *Automatic*, and enter *0.10* for forward under the *Forecast* section. Click *OK*. The graph should look similar to figure 20.

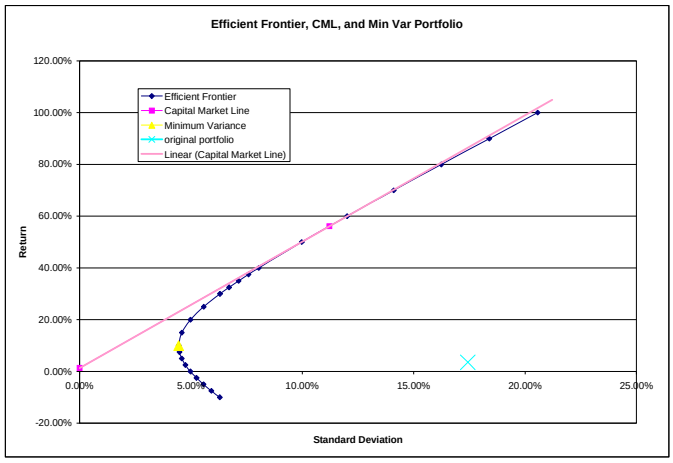


Figure 20

INTERPRETING THE GRAPH

The minimum variance portfolio is the mixture of risky stocks that reduces risk (standard deviation) to its lowest possible level. Every portfolio at and above the minimum variance portfolio is said to be on the *efficient frontier* and every

portfolio below the minimum variance portfolio is said to be on the *inefficient frontier*. Notice that any investor choosing a portfolio on the inefficient frontier can increase return without increasing risk (standard deviation) by moving to a portfolio that lies directly above on the efficient frontier.

The original portfolio, even though it is well diversified, is not efficiently diversified. By changing the weights invested in each stock we can significantly increase the return of the portfolio while decreasing risk.

The capital market line is the line that begins at the risk-free rate of return and "just touches" the efficient frontier. The point where the capital market line touches the efficient frontier is a special portfolio called the *market portfolio*. Investors at this point, have 100 percent of their funds invested in the Dow Jones index and 0 percent invested in the risk-free treasury bill. Other investors might be more risk averse and want to invest a portion of their funds in the risk-free treasury bill. They can accomplish this by lending (investing) some funds at the risk-free rate. Some investors might be so risk averse that they invest 100 percent in the risk-free treasury bill and 0 percent in the market portfolio. In this case, these investors will be at the point on the capital market line that intersects the y-axis.

Finally, notice that all investors will invest in some combination of the market portfolio and risk-free treasury bill. To illustrate this, suppose that some investor chose to invest in the minimum variance portfolio. Interestingly, this investor can increase return without increasing risk by alternatively investing *X* percent in the market portfolio and *(1-X)* percent in the risk-free treasury bill, and reach a point on the capital market line that is directly above the minimum variance portfolio.

WHAT IF

Suppose the risk-free rate of return changes. For example, suppose the United States Federal Reserve performs some open market operations over a period of time that causes the current risk-free rate of 0.0133…in cell C32 of the *Portfolio worksheet* to change to 0.075. Input the new risk-free rate in cell C32 and use *solver* to maximize the capital market line in cell B138 just like before. Excel will find a new solution. Save the scenario as before and give it the name *NEW MAX CML* to differentiate it from the original *MAX CML* scenario. Finally, perform a scenario summary like before. All of the original scenarios will appear plus the new one. Graph the *NEW MAX CML* with all of the other original information to see how the line changes.

CONCLUSION

We show that the skills students learn while in an introductory Excel spreadsheet class can be applied to modern portfolio theory without mathematical and statistical complexity. By showing students how the skills and concepts they are learning in a spreadsheet class can help them to understand concepts and theories in other business disciplines (e.g. finance) we address a common student learning issue. Namely, we help students overcome a disconnect of how the concepts and skills learned in one course can help them solve problems in another course. Furthermore, it introduces business students to the fundamental risk-return trade-off in finance that investment and introductory finance courses cover in more detail. Introducing students to portfolio theory prior to taking the finance course that most colleges of business require will help them better understand this important concept. Finally, this example helps instructors of introductory Excel spreadsheet classes illustrate the value of the skills they are teaching to non-information systems students.

TEACHING NOTES FOR THE CASE OF SIMULATING THE CHOICES OF MONEY MANAGERS BY APPLYING MODERN PORTFOLIO THEORY USING REAL STOCK PRICE DATA

CASE DESCRIPTION

As written, the audience for this case is business students who are taking an introductory Excel spreadsheet class. Nonetheless, this case can be adapted to other courses in finance and investments at the undergraduate level. Moreover, we use this case at the M.B.A. level for students who are taking a pre-requisite spreadsheet or finance course. Most of these students have non-business undergraduate degrees and have little or no spreadsheet skills or knowledge of finance theory.

This case is a 'how to' case and it simulates the process that a money manager uses in selecting assets during portfolio construction. In the introductory Excel class we cover the case over multiple weeks as topics are covered in the course. This case becomes a major student project at this level and it illustrates how the skills students learn in the course can be applied to another business discipline. In undergraduate investment and finance courses we use this case as a part of a semester project where students pick their own portfolio of stocks and get to decide their weights individually. We assign this part of the project as portfolio theory is

discussed in class. At the pre-requisite M.B.A. level we give students the case as written and have them complete the case prior to discussing portfolio theory. Since these students have little or no spreadsheet skills or knowledge of finance theory, it is helpful for these students to learn by doing.

This case has two specific learning objectives: (1) show students how the skills they learn in one course can be applied to another course, and (2) increase student spreadsheet skills and understanding of finance theory by simulating the process that money managers use in putting together a portfolio of assets.

CASE SYNOPSIS

This case places students in the role of a money manager who has the task of putting together a portfolio of stocks that will minimize risk and maximize return. Brinson, Singer, and Beebower (1991) show that asset allocation accounts for over 90 percent of the variation in portfolio returns. Thus, portfolio construction and management is one of the most important financial concepts. This case shows students how to construct a portfolio of stocks using real data from Yahoo! Finance.

ENDNOTES

[iii] Examples include *Investments* by Bodie, Kane, and Marcus, *Essentials of Investments* by Bodie, Kane, and Marcus, *Fundamentals of Financial Management* by Brigham and Houston, and *Intermediate Financial Management* by Brigham and Daves.

[iv] Examples include *Spreadsheet Modeling in Corporate Finance* by Holden, *Spreadsheet Modeling in Investments* by Holden, *Financial Analysis with Microsoft Excel 2002* by Mayes and Shank, and *Financial Modeling Using Excel and VBA* by Sengupta.

[v] We will explain these terms later in the paper.

[vi] Excel's scenario manager can handle up to 32 stocks in a portfolio. Beyond 32 stocks, Excel issues an error message.

[vii] The Adj. Close* column for stocks is a stock price whereas the Adj. Close* column for the 13-week U.S. Treasury bill is an annualized return in percent, not a bond price. One method to compute a monthly return for the bond is to divide the Adj. Close* column by 12 and to change the return from percent to decimal by dividing by 100.

[viii] Students should be familiar with arithmetic averages and standard deviations from a math course in high school or a finite math or business statistics course in college. This further emphasizes how skills learned in one class are used in another.

[ix] Students should be familiar with matrices from their finite math course. The use of matrices in this project further emphasizes how skills learned in one class are used in another.

[x] Adding a dollar sign in front of a row or column index makes the reference to that row or column absolute instead of relative. In this case, without using dollar signs in the formulas for the correlation matrix, we would have to go through this process 900 times (30x30). Using dollar signs reduces this number to only 30!

[xi] Shorting is a process where investors sell stock by borrowing it from another investor, then replace the borrowed stock at a later date by buying it in the market, hopefully at a lower price.

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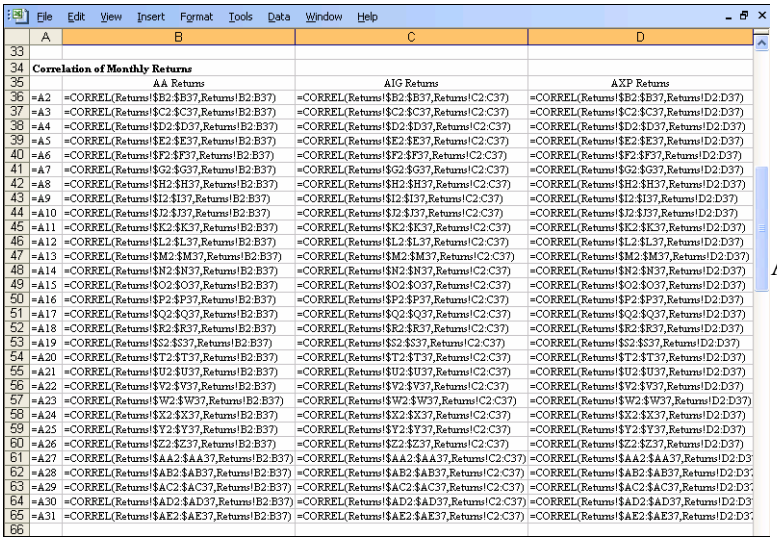
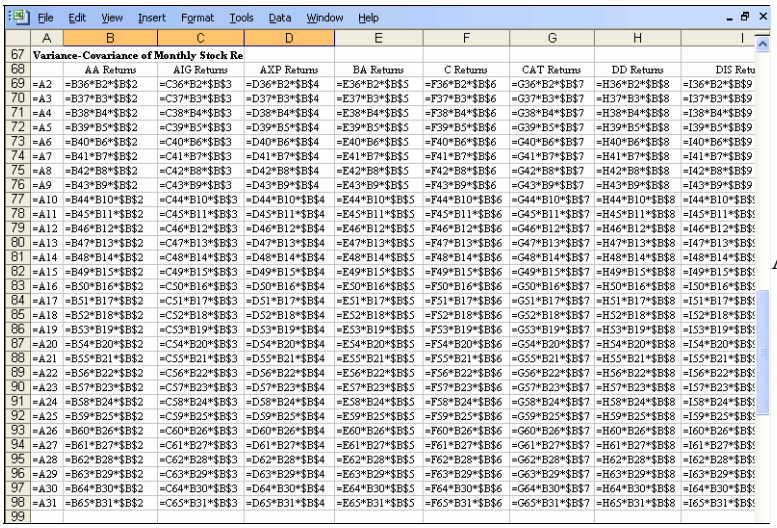


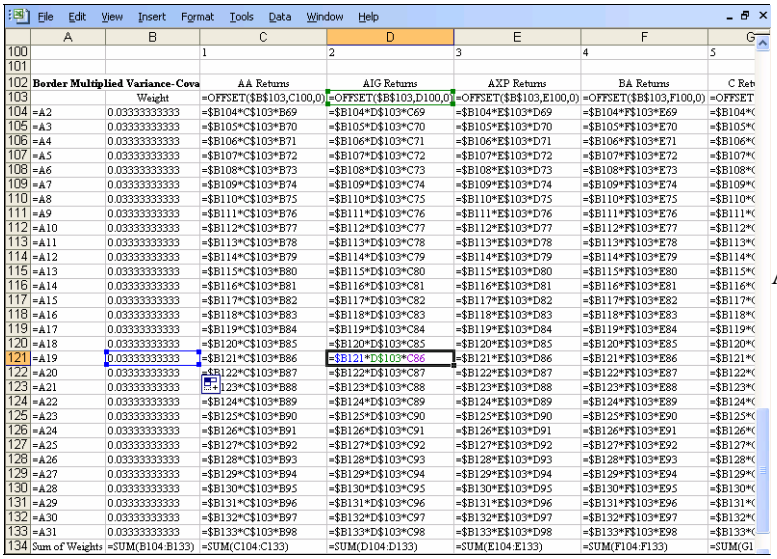
	A	B	C	D
33				
34	**Correlation of Monthly Returns**			
35		AA Returns	AIG Returns	AXP Returns
36	=A2	=CORREL(Returns!$B2:$B37,Returns!B2:B37)	=CORREL(Returns!$B2:$B37,Returns!C2:C37)	=CORREL(Returns!$B2:$B37,Returns!D2:D37)
37	=A3	=CORREL(Returns!$C2:$C37,Returns!B2:B37)	=CORREL(Returns!$C2:$C37,Returns!C2:C37)	=CORREL(Returns!$C2:$C37,Returns!D2:D37)
38	=A4	=CORREL(Returns!$D2:$D37,Returns!B2:B37)	=CORREL(Returns!$D2:$D37,Returns!C2:C37)	=CORREL(Returns!$D2:$D37,Returns!D2:D37)
39	=A5	=CORREL(Returns!$E2:$E37,Returns!B2:B37)	=CORREL(Returns!$E2:$E37,Returns!C2:C37)	=CORREL(Returns!$E2:$E37,Returns!D2:D37)
40	=A6	=CORREL(Returns!$F2:$F37,Returns!B2:B37)	=CORREL(Returns!$F2:$F37,Returns!C2:C37)	=CORREL(Returns!$F2:$F37,Returns!D2:D37)
41	=A7	=CORREL(Returns!$G2:$G37,Returns!B2:B37)	=CORREL(Returns!$G2:$G37,Returns!C2:C37)	=CORREL(Returns!$G2:$G37,Returns!D2:D37)
42	=A8	=CORREL(Returns!$H2:$H37,Returns!B2:B37)	=CORREL(Returns!$H2:$H37,Returns!C2:C37)	=CORREL(Returns!$H2:$H37,Returns!D2:D37)
43	=A9	=CORREL(Returns!$I2:$I37,Returns!B2:B37)	=CORREL(Returns!$I2:$I37,Returns!C2:C37)	=CORREL(Returns!$I2:$I37,Returns!D2:D37)
44	=A10	=CORREL(Returns!$J2:$J37,Returns!B2:B37)	=CORREL(Returns!$J2:$J37,Returns!C2:C37)	=CORREL(Returns!$J2:$J37,Returns!D2:D37)
45	=A11	=CORREL(Returns!$K2:$K37,Returns!B2:B37)	=CORREL(Returns!$K2:$K37,Returns!C2:C37)	=CORREL(Returns!$K2:$K37,Returns!D2:D37)
46	=A12	=CORREL(Returns!$L2:$L37,Returns!B2:B37)	=CORREL(Returns!$L2:$L37,Returns!C2:C37)	=CORREL(Returns!$L2:$L37,Returns!D2:D37)
47	=A13	=CORREL(Returns!$M2:$M37,Returns!B2:B37)	=CORREL(Returns!$M2:$M37,Returns!C2:C37)	=CORREL(Returns!$M2:$M37,Returns!D2:D37)
48	=A14	=CORREL(Returns!$N2:$N37,Returns!B2:B37)	=CORREL(Returns!$N2:$N37,Returns!C2:C37)	=CORREL(Returns!$N2:$N37,Returns!D2:D37)
49	=A15	=CORREL(Returns!$O2:$O37,Returns!B2:B37)	=CORREL(Returns!$O2:$O37,Returns!C2:C37)	=CORREL(Returns!$O2:$O37,Returns!D2:D37)
50	=A16	=CORREL(Returns!$P2:$P37,Returns!B2:B37)	=CORREL(Returns!$P2:$P37,Returns!C2:C37)	=CORREL(Returns!$P2:$P37,Returns!D2:D37)
51	=A17	=CORREL(Returns!$Q2:$Q37,Returns!B2:B37)	=CORREL(Returns!$Q2:$Q37,Returns!C2:C37)	=CORREL(Returns!$Q2:$Q37,Returns!D2:D37)
52	=A18	=CORREL(Returns!$R2:$R37,Returns!B2:B37)	=CORREL(Returns!$R2:$R37,Returns!C2:C37)	=CORREL(Returns!$R2:$R37,Returns!D2:D37)
53	=A19	=CORREL(Returns!$S2:$S37,Returns!B2:B37)	=CORREL(Returns!$S2:$S37,Returns!C2:C37)	=CORREL(Returns!$S2:$S37,Returns!D2:D37)
54	=A20	=CORREL(Returns!$T2:$T37,Returns!B2:B37)	=CORREL(Returns!$T2:$T37,Returns!C2:C37)	=CORREL(Returns!$T2:$T37,Returns!D2:D37)
55	=A21	=CORREL(Returns!$U2:$U37,Returns!B2:B37)	=CORREL(Returns!$U2:$U37,Returns!C2:C37)	=CORREL(Returns!$U2:$U37,Returns!D2:D37)
56	=A22	=CORREL(Returns!$V2:$V37,Returns!B2:B37)	=CORREL(Returns!$V2:$V37,Returns!C2:C37)	=CORREL(Returns!$V2:$V37,Returns!D2:D37)
57	=A23	=CORREL(Returns!$W2:$W37,Returns!B2:B37)	=CORREL(Returns!$W2:$W37,Returns!C2:C37)	=CORREL(Returns!$W2:$W37,Returns!D2:D37)
58	=A24	=CORREL(Returns!$X2:$X37,Returns!B2:B37)	=CORREL(Returns!$X2:$X37,Returns!C2:C37)	=CORREL(Returns!$X2:$X37,Returns!D2:D37)
59	=A25	=CORREL(Returns!$Y2:$Y37,Returns!B2:B37)	=CORREL(Returns!$Y2:$Y37,Returns!C2:C37)	=CORREL(Returns!$Y2:$Y37,Returns!D2:D37)
60	=A26	=CORREL(Returns!$Z2:$Z37,Returns!B2:B37)	=CORREL(Returns!$Z2:$Z37,Returns!C2:C37)	=CORREL(Returns!$Z2:$Z37,Returns!D2:D37)
61	=A27	=CORREL(Returns!$AA2:$AA37,Returns!B2:B37)	=CORREL(Returns!$AA2:$AA37,Returns!C2:C37)	=CORREL(Returns!$AA2:$AA37,Returns!D2:D3
62	=A28	=CORREL(Returns!$AB2:$AB37,Returns!B2:B37)	=CORREL(Returns!$AB2:$AB37,Returns!C2:C37)	=CORREL(Returns!$AB2:$AB37,Returns!D2:D3
63	=A29	=CORREL(Returns!$AC2:$AC37,Returns!B2:B37)	=CORREL(Returns!$AC2:$AC37,Returns!C2:C37)	=CORREL(Returns!$AC2:$AC37,Returns!D2:D3
64	=A30	=CORREL(Returns!$AD2:$AD37,Returns!B2:B37)	=CORREL(Returns!$AD2:$AD37,Returns!C2:C37)	=CORREL(Returns!$AD2:$AD37,Returns!D2:D3
65	=A31	=CORREL(Returns!$AE2:$AE37,Returns!B2:B37)	=CORREL(Returns!$AE2:$AE37,Returns!C2:C37)	=CORREL(Returns!$AE2:$AE37,Returns!D2:D3
66				

Appendix A



	A	B	C	D	E	F	G	H	I
67	**Variance-Covariance of Monthly Stock Re**								
68		AA Returns	AIG Returns	AXP Returns	BA Returns	C Returns	CAT Returns	DD Returns	DIS Retu
69	=A2	=B36*B2*$B$2	=C36*B2*$B$3	=D36*B2*$B$4	=E36*B2*$B$5	=F36*B2*$B$6	=G36*B2*$B$7	=H36*B2*$B$8	=I36*B2*$B$9
70	=A3	=B37*B3*$B$2	=C37*B3*$B$3	=D37*B3*$B$4	=E37*B3*$B$5	=F37*B3*$B$6	=G37*B3*$B$7	=H37*B3*$B$8	=I37*B3*$B$9
71	=A4	=B38*B4*$B$2	=C38*B4*$B$3	=D38*B4*$B$4	=E38*B4*$B$5	=F38*B4*$B$6	=G38*B4*$B$7	=H38*B4*$B$8	=I38*B4*$B$9
72	=A5	=B39*B5*$B$2	=C39*B5*$B$3	=D39*B5*$B$4	=E39*B5*$B$5	=F39*B5*$B$6	=G39*B5*$B$7	=H39*B5*$B$8	=I39*B5*$B$9
73	=A6	=B40*B6*$B$2	=C40*B6*$B$3	=D40*B6*$B$4	=E40*B6*$B$5	=F40*B6*$B$6	=G40*B6*$B$7	=H40*B6*$B$8	=I40*B6*$B$9
74	=A7	=B41*B7*$B$2	=C41*B7*$B$3	=D41*B7*$B$4	=E41*B7*$B$5	=F41*B7*$B$6	=G41*B7*$B$7	=H41*B7*$B$8	=I41*B7*$B$9
75	=A8	=B42*B8*$B$2	=C42*B8*$B$3	=D42*B8*$B$4	=E42*B8*$B$5	=F42*B8*$B$6	=G42*B8*$B$7	=H42*B8*$B$8	=I42*B8*$B$9
76	=A9	=B43*B9*$B$2	=C43*B9*$B$3	=D43*B9*$B$4	=E43*B9*$B$5	=F43*B9*$B$6	=G43*B9*$B$7	=H43*B9*$B$8	=I43*B9*$B$9
77	=A10	=B44*B10*$B$2	=C44*B10*$B$3	=D44*B10*$B$4	=E44*B10*$B$5	=F44*B10*$B$6	=G44*B10*$B$7	=H44*B10*$B$8	=I44*B10*B
78	=A11	=B45*B11*$B$2	=C45*B11*$B$3	=D45*B11*$B$4	=E45*B11*$B$5	=F45*B11*$B$6	=G45*B11*$B$7	=H45*B11*$B$8	=I45*B11*B
79	=A12	=B46*B12*$B$2	=C46*B12*$B$3	=D46*B12*$B$4	=E46*B12*$B$5	=F46*B12*$B$6	=G46*B12*$B$7	=H46*B12*$B$8	=I46*B12*B
80	=A13	=B47*B13*$B$2	=C47*B13*$B$3	=D47*B13*$B$4	=E47*B13*$B$5	=F47*B13*$B$6	=G47*B13*$B$7	=H47*B13*$B$8	=I47*B13*B
81	=A14	=B48*B14*$B$2	=C48*B14*$B$3	=D48*B14*$B$4	=E48*B14*$B$5	=F48*B14*$B$6	=G48*B14*$B$7	=H48*B14*$B$8	=I48*B14*B
82	=A15	=B49*B15*$B$2	=C49*B15*$B$3	=D49*B15*$B$4	=E49*B15*$B$5	=F49*B15*$B$6	=G49*B15*$B$7	=H49*B15*$B$8	=I49*B15*B
83	=A16	=B50*B16*$B$2	=C50*B16*$B$3	=D50*B16*$B$4	=E50*B16*$B$5	=F50*B16*$B$6	=G50*B16*$B$7	=H50*B16*$B$8	=I50*B16*B
84	=A17	=B51*B17*$B$2	=C51*B17*$B$3	=D51*B17*$B$4	=E51*B17*$B$5	=F51*B17*$B$6	=G51*B17*$B$7	=H51*B17*$B$8	=I51*B17*B
85	=A18	=B52*B18*$B$2	=C52*B18*$B$3	=D52*B18*$B$4	=E52*B18*$B$5	=F52*B18*$B$6	=G52*B18*$B$7	=H52*B18*$B$8	=I52*B18*B
86	=A19	=B53*B19*$B$2	=C53*B19*$B$3	=D53*B19*$B$4	=E53*B19*$B$5	=F53*B19*$B$6	=G53*B19*$B$7	=H53*B19*$B$8	=I53*B19*B
87	=A20	=B54*B20*$B$2	=C54*B20*$B$3	=D54*B20*$B$4	=E54*B20*$B$5	=F54*B20*$B$6	=G54*B20*$B$7	=H54*B20*$B$8	=I54*B20*B
88	=A21	=B55*B21*$B$2	=C55*B21*$B$3	=D55*B21*$B$4	=E55*B21*$B$5	=F55*B21*$B$6	=G55*B21*$B$7	=H55*B21*$B$8	=I55*B21*B
89	=A22	=B56*B22*$B$2	=C56*B22*$B$3	=D56*B22*$B$4	=E56*B22*$B$5	=F56*B22*$B$6	=G56*B22*$B$7	=H56*B22*$B$8	=I56*B22*B
90	=A23	=B57*B23*$B$2	=C57*B23*$B$3	=D57*B23*$B$4	=E57*B23*$B$5	=F57*B23*$B$6	=G57*B23*$B$7	=H57*B23*$B$8	=I57*B23*B
91	=A24	=B58*B24*$B$2	=C58*B24*$B$3	=D58*B24*$B$4	=E58*B24*$B$5	=F58*B24*$B$6	=G58*B24*$B$7	=H58*B24*$B$8	=I58*B24*B
92	=A25	=B59*B25*$B$2	=C59*B25*$B$3	=D59*B25*$B$4	=E59*B25*$B$5	=F59*B25*$B$6	=G59*B25*$B$7	=H59*B25*$B$8	=I59*B25*B
93	=A26	=B60*B26*$B$2	=C60*B26*$B$3	=D60*B26*$B$4	=E60*B26*$B$5	=F60*B26*$B$6	=G60*B26*$B$7	=H60*B26*$B$8	=I60*B26*B
94	=A27	=B61*B27*$B$2	=C61*B27*$B$3	=D61*B27*$B$4	=E61*B27*$B$5	=F61*B27*$B$6	=G61*B27*$B$7	=H61*B27*$B$8	=I61*B27*B
95	=A28	=B62*B28*$B$2	=C62*B28*$B$3	=D62*B28*$B$4	=E62*B28*$B$5	=F62*B28*$B$6	=G62*B28*$B$7	=H62*B28*$B$8	=I62*B28*B
96	=A29	=B63*B29*$B$2	=C63*B29*$B$3	=D63*B29*$B$4	=E63*B29*$B$5	=F63*B29*$B$6	=G63*B29*$B$7	=H63*B29*$B$8	=I63*B29*B
97	=A30	=B64*B30*$B$2	=C64*B30*$B$3	=D64*B30*$B$4	=E64*B30*$B$5	=F64*B30*$B$6	=G64*B30*$B$7	=H64*B30*$B$8	=I64*B30*B
98	=A31	=B65*B31*$B$2	=C65*B31*$B$3	=D65*B31*$B$4	=E65*B31*$B$5	=F65*B31*$B$6	=G65*B31*$B$7	=H65*B31*$B$8	=I65*B31*B
99									

Appendix B



	A	B	C	D	E	F	G
100			1	2	3	4	5
101							
102	**Border Multiplied Variance-Cova**		AA Returns	AIG Returns	AXP Returns	BA Returns	C Retu
103		Weight	=OFFSET($B$103,C100,0)	=OFFSET($B$103,D100,0)	=OFFSET($B$103,E100,0)	=OFFSET($B$103,F100,0)	=OFFSET
104	=A2	0.03333333333	=$B104*C$103*B69	=$B104*D$103*C69	=$B104*E$103*D69	=$B104*F$103*E69	=$B104*(
105	=A3	0.03333333333	=$B105*C$103*B70	=$B105*D$103*C70	=$B105*E$103*D70	=$B105*F$103*E70	=$B105*(
106	=A4	0.03333333333	=$B106*C$103*B71	=$B106*D$103*C71	=$B106*E$103*D71	=$B106*F$103*E71	=$B106*(
107	=A5	0.03333333333	=$B107*C$103*B72	=$B107*D$103*C72	=$B107*E$103*D72	=$B107*F$103*E72	=$B107*(
108	=A6	0.03333333333	=$B108*C$103*B73	=$B108*D$103*C73	=$B108*E$103*D73	=$B108*F$103*E73	=$B108*(
109	=A7	0.03333333333	=$B109*C$103*B74	=$B109*D$103*C74	=$B109*E$103*D74	=$B109*F$103*E74	=$B109*(
110	=A8	0.03333333333	=$B110*C$103*B75	=$B110*D$103*C75	=$B110*E$103*D75	=$B110*F$103*E75	=$B110*(
111	=A9	0.03333333333	=$B111*C$103*B76	=$B111*D$103*C76	=$B111*E$103*D76	=$B111*F$103*E76	=$B111*(
112	=A10	0.03333333333	=$B112*C$103*B77	=$B112*D$103*C77	=$B112*E$103*D77	=$B112*F$103*E77	=$B112*(
113	=A11	0.03333333333	=$B113*C$103*B78	=$B113*D$103*C78	=$B113*E$103*D78	=$B113*F$103*E78	=$B113*(
114	=A12	0.03333333333	=$B114*C$103*B79	=$B114*D$103*C79	=$B114*E$103*D79	=$B114*F$103*E79	=$B114*(
115	=A13	0.03333333333	=$B115*C$103*B80	=$B115*D$103*C80	=$B115*E$103*D80	=$B115*F$103*E80	=$B115*(
116	=A14	0.03333333333	=$B116*C$103*B81	=$B116*D$103*C81	=$B116*E$103*D81	=$B116*F$103*E81	=$B116*(
117	=A15	0.03333333333	=$B117*C$103*B82	=$B117*D$103*C82	=$B117*E$103*D82	=$B117*F$103*E82	=$B117*(
118	=A16	0.03333333333	=$B118*C$103*B83	=$B118*D$103*C83	=$B118*E$103*D83	=$B118*F$103*E83	=$B118*(
119	=A17	0.03333333333	=$B119*C$103*B84	=$B119*D$103*C84	=$B119*E$103*D84	=$B119*F$103*E84	=$B119*(
120	=A18	0.03333333333	=$B120*C$103*B85	=$B120*D$103*C85	=$B120*E$103*D85	=$B120*F$103*E85	=$B120*(
121	=A19	0.03333333333	=$B121*C$103*B86	=$B121*D$103*C86	=$B121*E$103*D86	=$B121*F$103*E86	=$B121*(
122	=A20	0.03333333333	=$B122*C$103*B87	=$B122*D$103*C87	=$B122*E$103*D87	=$B122*F$103*E87	=$B122*(
123	=A21	0.03333333333	=$B123*C$103*B88	=$B123*D$103*C88	=$B123*E$103*D88	=$B123*F$103*E88	=$B123*(
124	=A22	0.03333333333	=$B124*C$103*B89	=$B124*D$103*C89	=$B124*E$103*D89	=$B124*F$103*E89	=$B124*(
125	=A23	0.03333333333	=$B125*C$103*B90	=$B125*D$103*C90	=$B125*E$103*D90	=$B125*F$103*E90	=$B125*(
126	=A24	0.03333333333	=$B126*C$103*B91	=$B126*D$103*C91	=$B126*E$103*D91	=$B126*F$103*E91	=$B126*(
127	=A25	0.03333333333	=$B127*C$103*B92	=$B127*D$103*C92	=$B127*E$103*D92	=$B127*F$103*E92	=$B127*(
128	=A26	0.03333333333	=$B128*C$103*B93	=$B128*D$103*C93	=$B128*E$103*D93	=$B128*F$103*E93	=$B128*(
129	=A27	0.03333333333	=$B129*C$103*B94	=$B129*D$103*C94	=$B129*E$103*D94	=$B129*F$103*E94	=$B129*(
130	=A28	0.03333333333	=$B130*C$103*B95	=$B130*D$103*C95	=$B130*E$103*D95	=$B130*F$103*E95	=$B130*(
131	=A29	0.03333333333	=$B131*C$103*B96	=$B131*D$103*C96	=$B131*E$103*D96	=$B131*F$103*E96	=$B131*(
132	=A30	0.03333333333	=$B132*C$103*B97	=$B132*D$103*C97	=$B132*E$103*D97	=$B132*F$103*E97	=$B132*(
133	=A31	0.03333333333	=$B133*C$103*B98	=$B133*D$103*C98	=$B133*E$103*D98	=$B133*F$103*E98	=$B133*(
134	Sum of Weights	=SUM(B104:B133)	=SUM(C104:C133)	=SUM(D104:D133)	=SUM(E104:E133)	=SUM(F104:F133)	=SUM(G1

Appendix C

ECONOMICS ARTICLES