Stuart School of Business
ILLINOIS INSTITUTE OF TECHNOLOGY

VPM (MSF 504)
Homework 4: Due May 1

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1. Find the covariance matrix of excess returns using the sample data. Also find the one factor structural covariance matrix, using betas from a regression of stock excess returns against SPY (S&P 500) excess returns. Multiply the covariance matrix by 12 (to annualize the variances and covariances) and report the annualized covariance matrix

	MMM	ABT	ACN	ADBE	AMZN	GOOG	ADM	AMAT	BAC	BK	BHI	CVX	EBAY	HAL	UPS	DIS	WMT	YUM	LUV
MMM	0.0194	0.0132	0.0119	0.0077	0.0124	0.0071	0.0034	0.0241	0.0087	0.0110	0.0060	0.0148	0.0115	0.0081	0.0132	0.0127	0.0029	0.0060	0.0133
ABT	0.0132	0.0372	0.0153	0.0152	0.0256	0.0208	0.0112	0.0216	0.0150	0.0128	0.0056	0.0116	0.0295	0.0105	0.0089	0.0211	0.0024	0.0109	0.0131
ACN	0.0119	0.0153	0.0322	0.0136	0.0177	0.0161	0.0068	0.0187	0.0197	0.0166	0.0023	0.0156	0.0142	0.0069	0.0113	0.0157	0.0032	0.0094	0.0064
ADBE	0.0077	0.0152	0.0136	0.0354	0.0213	0.0127	0.0107	0.0284	0.0176	0.0136	0.0036	0.0099	0.0145	0.0061	0.0094	0.0160	-0.0016	0.0177	0.0060
AMZN	0.0124	0.0256	0.0177	0.0213	0.0786	0.0310	0.0094	0.0203	0.0118	0.0155	0.0134	0.0082	0.0327	0.0145	0.0090	0.0165	-0.0023	0.0103	0.0182
GOOG	0.0071	0.0208	0.0161	0.0127	0.0310	0.0427	0.0060	0.0143	0.0138	0.0069	0.0077	0.0057	0.0223	0.0102	0.0044	0.0139	-0.0033	-0.0029	0.0115
ADM	0.0094	0.0112	0.0068	0.0107	0.0094	0.0060	0.0486	0.0151	0.0126	0.0158	0.0101	0.0103	0.0115	0.0037	0.0112	0.0135	0.0031	0.0067	0.0141
AMAT	0.0241	0.0216	0.0187	0.0284	0.0203	0.0143	0.0151	0.0785	0.0297	0.0267	0.0151	0.0233	0.0278	0.0170	0.0179	0.0175	0.0031	0.0117	0.0196
BAC	0.0087	0.0150	0.0197	0.0176	0.0118	0.0138	0.0126	0.0297	0.0912	0.0445	0.0016	0.0177	0.0179	0.0052	0.0153	0.0187	-0.0059	0.0109	0.0119
BK	0.0110	0.0128	0.0166	0.0136	0.0155	0.0069	0.0158	0.0267	0.0445	0.0449	0.0117	0.0210	0.0146	0.0153	0.0154	0.0158	-0.0024	0.0098	0.0082
BHI	0.0060	0.0056	0.0023	0.0036	0.0134	0.0077	0.0101	0.0151	0.0016	0.0117	0.0589	0.0153	0.0126	0.0451	0.0057	0.0121	-0.0002	0.0062	0.0229
CVX	0.0148	0.0116	0.0156	0.0099	0.0082	0.0057	0.0103	0.0233	0.0177	0.0210	0.0153	0.0349	0.0081	0.0309	0.0119	0.0164	-0.0018	0.0066	0.0046
EBAY	0.0115	0.0295	0.0142	0.0145	0.0327	0.0223	0.0115	0.0278	0.0179	0.0146	0.0126	0.0081	0.0638	0.0088	0.0058	0.0181	-0.0084	0.0067	0.0052
HAL	0.0081	0.0105	0.0069	0.0061	0.0145	0.0102	0.0037	0.0170	0.0052	0.0153	0.0451	0.0309	0.0088	0.0784	0.0058	0.0160	-0.0112	0.0052	0.0064
UPS	0.0132	0.0089	0.0113	0.0094	0.0090	0.0044	0.0112	0.0179	0.0153	0.0154	0.0057	0.0119	0.0058	0.0058	0.0215	0.0123	0.0043	0.0095	0.0121
DIS	0.0127	0.0211	0.0157	0.0160	0.0165	0.0139	0.0135	0.0175	0.0187	0.0158	0.0121	0.0164	0.0181	0.0160	0.0123	0.0321	0.0007	0.0068	0.0149
WMT	0.0029	0.0024	0.0032	-0.0016	-0.0023	-0.0033	0.0031	0.0031	-0.0059	-0.0024	-0.0002	-0.0018	-0.0084	-0.0112	0.0043	0.0007	0.0265	0.0109	0.0053
YUM	0.0060	0.0109	0.0094	0.0177	0.0103	-0.0029	0.0067	0.0117	0.0109	0.0098	0.0062	0.0066	0.0067	0.0052	0.0095	0.0068	0.0109	0.0401	-0.0082
LUV	0.0133	0.0131	0.0064	0.0060	0.0182	0.0115	0.0141	0.0196	0.0119	0.0082	0.0229	0.0046	0.0052	0.0064	0.0121	0.0149	0.0053	-0.0082	0.0733

2. Find the one factor structural covariance matrix, using betas from a regression of stock excess returns against SPY (S&P 500) excess returns. Estimate and report a 19-by-19 covariance matrix of monthly excess returns for the 19 stocks using $\mathbf{b}\mathbf{b}'\hat{\sigma}^2_{SPY} + \mathbf{\Sigma}_\varepsilon$, where $\mathbf{\Sigma}_\varepsilon$ is a 19-by-19 matrix of residual returns with all off-diagonals are zeros. Multiply the covariance matrix by 12 and report this annualized structural covariance matrix.

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	SPY	MMM	ABT	ACN	ADBE	AMZN	GOOG	ADM	AMAT	BAC	BK	BHI	CVX	EBAY	HAL	UPS	DIS	WMT	YUM	LUV
Betas	1.000	1.039	1.393	1.162	1.051	1.400	0.999	0.910	1.805	1.467	1.321	0.737	1.217	1.307	0.994	0.910	1.247	0.077	0.747	0.889
Annualized Variance	0.011	0.019	0.037	0.032	0.035	0.079	0.043	0.049	0.078	0.091	0.045	0.059	0.035	0.070	0.078	0.021	0.032	0.026	0.040	0.073

One factor structural covariance matrix from betas of excess return:

Betas		MMM	ABT	ACN	ADBE	AMZN	GOOG	ADM	AMAT	BAC	BK	BHI	CVX	EBAY	HAL	UPS	DIS	WMT	YUM	LUV
1.039	MMM	0.0194	0.0153	0.0128	0.0116	0.0154	0.0110	0.0100	0.0198	0.0161	0.0145	0.0081	0.0134	0.0144	0.0103	0.0100	0.0137	0.0008	0.0082	0.0098
1.393	ABT	0.0153	0.0372	0.0171	0.0155	0.0206	0.0147	0.0134	0.0266	0.0216	0.0195	0.0109	0.0173	0.0193	0.0146	0.0134	0.0184	0.0011	0.0110	0.0131
1.162	ACN	0.0128	0.0171	0.0322	0.0129	0.0172	0.0123	0.0112	0.0222	0.0180	0.0162	0.0091	0.0150	0.0161	0.0122	0.0112	0.0153	0.0009	0.0092	0.0109
1.051	ADBE	0.0116	0.0155	0.0129	0.0354	0.0156	0.0111	0.0101	0.0201	0.0163	0.0147	0.0082	0.0135	0.0145	0.0111	0.0101	0.0139	0.0009	0.0083	0.0099
1.400	AMZN	0.0154	0.0206	0.0172	0.0156	0.0786	0.0148	0.0135	0.0267	0.0217	0.0196	0.0109	0.0180	0.0194	0.0147	0.0135	0.0185	0.0011	0.0111	0.0132
0.999	GOOG	0.0110	0.0147	0.0123	0.0111	0.0148	0.0427	0.0096	0.0191	0.0155	0.0140	0.0078	0.0129	0.0138	0.0105	0.0096	0.0132	0.0008	0.0079	0.0094
0.910	ADM	0.0100	0.0134	0.0112	0.0101	0.0135	0.0096	0.0486	0.0174	0.0141	0.0127	0.0071	0.0117	0.0126	0.0096	0.0088	0.0120	0.0007	0.0072	0.0086
1.805	AMAT	0.0198	0.0266	0.0222	0.0201	0.0267	0.0191	0.0174	0.0785	0.0280	0.0252	0.0141	0.0232	0.0250	0.0190	0.0174	0.0238	0.0015	0.0143	0.0170
1.467	BAC	0.0161	0.0216	0.0180	0.0163	0.0217	0.0155	0.0141	0.0280	0.0912	0.0205	0.0114	0.0183	0.0203	0.0154	0.0141	0.0193	0.0012	0.0116	0.0138
1.321	BK	0.0145	0.0195	0.0162	0.0147	0.0196	0.0140	0.0127	0.0252	0.0205	0.0449	0.0103	0.0170	0.0183	0.0139	0.0127	0.0174	0.0011	0.0104	0.0124
0.737	BHI	0.0081	0.0109	0.0091	0.0082	0.0109	0.0078	0.0071	0.0141	0.0114	0.0103	0.0589	0.0095	0.0102	0.0078	0.0071	0.0097	0.0006	0.0058	0.0069
1.217	CVX	0.0134	0.0173	0.0150	0.0135	0.0180	0.0129	0.0117	0.0232	0.0189	0.0170	0.0095	0.0349	0.0168	0.0128	0.0117	0.0161	0.0010	0.0096	0.0114
1.307	EBAY	0.0144	0.0193	0.0161	0.0145	0.0194	0.0138	0.0126	0.0250	0.0203	0.0183	0.0102	0.0168	0.0638	0.0137	0.0126	0.0172	0.0011	0.0103	0.0123
0.994	HAL	0.0103	0.0146	0.0122	0.0111	0.0147	0.0105	0.0096	0.0190	0.0154	0.0139	0.0078	0.0128	0.0137	0.0784	0.0096	0.0131	0.0008	0.0079	0.0093
0.910	UPS	0.0100	0.0134	0.0112	0.0101	0.0135	0.0096	0.0088	0.0174	0.0141	0.0127	0.0071	0.0117	0.0126	0.0096	0.0215	0.0120	0.0007	0.0072	0.0086
1.247	DIS	0.0137	0.0184	0.0153	0.0139	0.0185	0.0132	0.0120	0.0238	0.0193	0.0174	0.0097	0.0161	0.0172	0.0131	0.0120	0.0321	0.0010	0.0099	0.0117
0.077	WMT	0.0008	0.0011	0.0009	0.0009	0.0011	0.0008	0.0007	0.0015	0.0012	0.0011	0.0006	0.0010	0.0011	0.0008	0.0007	0.0010	0.0265	0.0006	0.0007
0.747	YUM	0.0082	0.0110	0.0092	0.0083	0.0111	0.0079	0.0072	0.0143	0.0116	0.0104	0.0058	0.0096	0.0103	0.0079	0.0072	0.0099	0.0006	0.0401	0.0070
0.889	LUV	0.0098	0.0131	0.0109	0.0099	0.0132	0.0094	0.0086	0.0170	0.0138	0.0124	0.0069	0.0114	0.0123	0.0093	0.0086	0.0117	0.0007	0.0070	0.0733

3. Shrink the sample covariance matrix by using $\hat{\Omega}_{shrink} = \frac{1}{2}\hat{\Omega}_{sample} + \frac{1}{2}\hat{\Omega}_{1-factor}$. Yeah, you know the drill: report this covariance matrix

Shrunken covariance matrix of excess return:

	MMM	ABT	ACN	ADBE	AMZN	GOOG	ADM	AMAT	BAC	BK	BHI	CVX	EBAY	HAL	UPS	DIS	WMT	YUM	LUV
MMM	0.0194	0.0143	0.0123	0.0096	0.0139	0.0091	0.0097	0.0219	0.0124	0.0127	0.0070	0.0141	0.0123	0.0095	0.0116	0.0132	0.0019	0.0071	0.0115
ABT	0.0143	0.0372	0.0162	0.0153	0.0231	0.0178	0.0123	0.0241	0.0183	0.0161	0.0083	0.0148	0.0244	0.0126	0.0111	0.0197	0.0018	0.0110	0.0131
ACN	0.0123	0.0162	0.0322	0.0133	0.0175	0.0142	0.0090	0.0204	0.0189	0.0164	0.0057	0.0153	0.0152	0.0096	0.0113	0.0155	0.0021	0.0093	0.0087
ADBE	0.0096	0.0153	0.0133	0.0354	0.0184	0.0119	0.0104	0.0242	0.0170	0.0142	0.0059	0.0117	0.0145	0.0086	0.0098	0.0149	-0.0004	0.0130	0.0079
AMZN	0.0139	0.0231	0.0175	0.0184	0.0786	0.0229	0.0114	0.0235	0.0168	0.0175	0.0121	0.0131	0.0260	0.0146	0.0112	0.0175	-0.0006	0.0107	0.0157
GOOG	0.0091	0.0178	0.0142	0.0119	0.0229	0.0427	0.0078	0.0167	0.0147	0.0104	0.0078	0.0093	0.0180	0.0103	0.0070	0.0135	-0.0012	0.0025	0.0105
ADM	0.0097	0.0123	0.0090	0.0104	0.0114	0.0078	0.0486	0.0163	0.0134	0.0142	0.0086	0.0110	0.0120	0.0066	0.0100	0.0127	0.0019	0.0069	0.0113
AMAT	0.0219	0.0241	0.0204	0.0242	0.0235	0.0167	0.0163	0.0785	0.0288	0.0260	0.0146	0.0233	0.0264	0.0180	0.0176	0.0206	0.0023	0.0130	0.0183
BAC	0.0124	0.0183	0.0189	0.0170	0.0168	0.0147	0.0134	0.0288	0.0912	0.0325	0.0065	0.0183	0.0191	0.0103	0.0147	0.0190	-0.0023	0.0113	0.0129
BK	0.0127	0.0161	0.0164	0.0142	0.0175	0.0104	0.0142	0.0260	0.0325	0.0443	0.0110	0.0190	0.0165	0.0146	0.0140	0.0166	-0.0007	0.0101	0.0103
BHI	0.0070	0.0083	0.0057	0.0059	0.0121	0.0078	0.0086	0.0146	0.0065	0.0110	0.0589	0.0124	0.0114	0.0264	0.0064	0.0109	0.0002	0.0060	0.0143
CVX	0.0141	0.0148	0.0153	0.0117	0.0131	0.0093	0.0110	0.0233	0.0183	0.0190	0.0124	0.0343	0.0125	0.0219	0.0118	0.0162	-0.0004	0.0081	0.0080
EBAY	0.0123	0.0244	0.0152	0.0145	0.0260	0.0180	0.0120	0.0264	0.0191	0.0165	0.0114	0.0125	0.0638	0.0113	0.0092	0.0177	-0.0037	0.0085	0.0088
HAL	0.0095	0.0126	0.0096	0.0086	0.0146	0.0103	0.0066	0.0180	0.0103	0.0146	0.0264	0.0219	0.0113	0.0784	0.0077	0.0145	-0.0052	0.0065	0.0079
UPS	0.0116	0.0111	0.0113	0.0098	0.0112	0.0070	0.0100	0.0176	0.0147	0.0140	0.0064	0.0118	0.0092	0.0077	0.0215	0.0121	0.0025	0.0083	0.0103
DIS	0.0132	0.0197	0.0155	0.0149	0.0175	0.0135	0.0127	0.0206	0.0190	0.0166	0.0109	0.0162	0.0177	0.0145	0.0121	0.0321	0.0009	0.0083	0.0133
WMT	0.0019	0.0018	0.0021	-0.0004	-0.0006	-0.0012	0.0019	0.0023	-0.0023	-0.0007	0.0002	-0.0004	-0.0037	-0.0052	0.0025	0.0009	0.0265	0.0058	0.0030
YUM	0.0071	0.0110	0.0093	0.0130	0.0107	0.0025	0.0069	0.0130	0.0113	0.0101	0.0060	0.0081	0.0085	0.0065	0.0083	0.0083	0.0058	0.0401	-0.0006
LUV	0.0115	0.0131	0.0087	0.0079	0.0157	0.0105	0.0113	0.0183	0.0129	0.0103	0.0149	0.0080	0.0088	0.0079	0.0103	0.0133	0.0030	-0.0006	0.0133

4. We have annual risk-free rate of 3%, and we expect a **reference portfolio** risk premium of 6% over the next year. Using this information—along with the stocks' market caps—find the expected returns of the reference portfolio. Report these expected returns.

	Expected return	Weights	Risk-free rate	Expected return of the reference portfolio
MMM	4.02%	4.43%	3.00%	7.02%
ABT	6.03%	2.95%	3.00%	9.03%
ACN	5.10%	2.83%	3.00%	8.10%
ADBE	4.67%	2.53%	3.00%	7.67%
AMZN	9.47%	16.38%	3.00%	12.47%
GOOG	6.35%	23.00%	3.00%	9.35%
ADM	3.58%	1.01%	3.00%	6.58%
AMAT	7.24%	1.61%	3.00%	10.24%
BAC	7.60%	8.34%	3.00%	10.60%
BK	5.47%	1.31%	3.00%	8.47%
BHI	3.27%	1.00%	3.00%	6.27%
CVX	4.86%	7.93%	3.00%	7.86%
EBAY	5.39%	1.46%	3.00%	8.39%
HAL	4.29%	1.66%	3.00%	7.29%
UPS	3.61%	3.59%	3.00%	6.61%
DIS	5.46%	7.11%	3.00%	8.46%
WMT	0.72%	8.81%	3.00%	3.72%
YUM	2.75%	0.89%	3.00%	5.75%
LUV	4.14%	1.30%	3.00%	7.14%

5. **Views:** Our crack research staff of analysts has the following views that we wish to incorporate into our analysis, Black-Litterman style:

   a) ADM, AMAT, and DIS will each under-perform their reference returns by 3% over the next year, ±4% with 90% confidence. (This is an ex ante alpha for these stocks of –3%, so the view is that the returns on these stocks will be 3% less than the ores you calculated in part (4).

   b) AMZN is expected to have a total return of 16% over the next year, ±5%, with 90% confidence.

   c) LUV returns will outperform UPS returns by 4% over the next year, ±5%, with 90% confidence.

   Report the Portfolio of Positions, **P**, the view vector of expected returns, **v** (little "v"), and Covariance Matrix of the Views, **V** (big "V").

Absolute and relative views:

	v	R	cst
ADM	3.58%	6.58%	-3.00%
AMAT	7.24%	10.24%	-3.00%
DIS	5.46%	8.46%	-3.00%
AMZN	16.00%	ND	ND
LUV-UPS	4.00%	ND	ND

	Varinace of the view	Covariance Matrix V				
ADM	0.000591273	0.00059127	0	0	0	0
AMAT	0.000591273	0	0.00059127	0	0	0
DIS	0.000591273	0	0	0.00059127	0	0
AMZN	0.000923864	0	0	0	0.00092386	0
LUV-UPS	0.000923864	0	0	0	0	0.000923864

6. Use $\tau = 0.3$ and $\hat{\Omega}_{shrink}$ from part (3)—and equation $\bar{\mathbf{r}} = \left[\left(\tau\hat{\Omega}_{shrink}\right)^{-1} + \mathbf{P}'\mathbf{V}^{-1}\mathbf{P}\right]^{-1}\left[\left(\tau\hat{\Omega}_{shrink}\right)^{-1}\Pi + \mathbf{P}'\mathbf{V}^{-1}\mathbf{v}\right]$—to estimate the Black-Litterman weighted vector of expected returns for all 19 stocks.

Measure lack of confidence in reference view: $\left(\tau\hat{\Omega}_{shrink}\right)^{-1}$

	MMM	ABT	ACN	ADBE	AMZN	GOOG	ADM	AMAT	BAC	BK	BHI	CVX	EBAY	HAL	UPS	DIS	WMT	YUM	LUV
MMM	392.4397941	-36.280799	-27.507915	15.6728198	-3.8668101	-0.4677694	-8.43760685	-44.75433	9.15404631	0.67408091	4.80754539	-58.484658	-7.3476954	2.67050431	-85.482745	-29.208978	-7.0975135	-5.7871938	-17.098735
ABT	-36.2807932	186.688448	-10.582911	-8.6572301	-11.703656	-26.383655	-4.74785554	-5.5621155	-1.4306377	-2.3741474	7.32181729	-5.1300688	-26.162012	-3.538545	4.89487767	-44.149367	-9.4116198	-15.327018	-6.2893376
ACN	-27.5079153	-10.582911	178.184773	-11.371496	-6.5266243	-22.647247	4.32078397	-1.8272079	-6.5924541	-14.313519	7.04678538	-26.162301	-3.7537916	2.81435319	-16.335526	-19.662714	-10.502202	-7.7313618	1.77766004
ADBE	15.67281981	-8.6572301	-11.371496	150.683554	-10.32561	-9.2300082	-5.90268888	-24.830272	-2.6090344	-2.5541224	4.34550472	-2.1361736	0.49330972	2.66246593	-8.1043493	-26.426792	12.363801	-28.051928	-0.0617814
AMZN	-3.86681007	-11.703656	-6.5266243	-10.32561	60.408721	-15.711143	0.35797724	1.32502086	2.20037343	-5.4781418	-2.55354616	4.7930694	-7.636555	-2.2087133	-0.7307714	0.26081097	2.26293038	-3.7229532	-3.360766
GOOG	-0.46776941	-26.383655	-22.647247	-9.2300082	-15.711143	112.914868	-0.6034334	-1.3642895	-4.622041	5.87330365	-3.4298138	5.5816721	-6.4653283	-3.1893928	2.91767143	-7.4939429	3.8385262	14.6925024	-1.7450312
ADM	-8.43760685	-4.7478555	4.32078398	-5.9026889	0.35797724	-0.6034334	83.56784795	-0.4837755	0.01020023	-10.344221	-3.87263325	-4.6628478	-2.6562661	3.20260003	-11.877084	-10.031492	-3.3998686	-1.4300674	-4.1331048
AMAT	-44.7543297	-5.5621155	-1.8272079	-24.830272	1.32502086	-1.3642895	-0.48377547	76.4323172	-4.8905336	-9.6887936	-3.47155443	-3.325954	-8.1805537	-1.8824772	-6.2157694	7.76015578	-5.2075152	1.68287253	-3.3463475
BAC	9.154046313	-1.4306377	-6.5924541	-2.6090344	2.20037343	-4.622041	0.010200234	-4.8905336	53.2646674	-27.61933	3.5981594	-3.8270769	-1.5947391	2.70932061	-7.0306798	-7.0342774	6.33783804	-3.4451469	-2.5943421
BK	0.674080912	-2.3741474	-14.313519	-2.5541224	-5.4781418	5.87330365	-10.3442214	-9.6887936	-27.61933	134.765683	-5.24876767	-24.010344	-2.6243743	-2.6580367	-25.296776	-6.6434113	5.82435317	-2.8705005	1.45332432
BHI	4.80754539	7.32181729	7.04678538	4.34550472	-2.5595462	-3.4298138	-3.87263325	-3.4715544	3.5981594	-5.2487677	73.0484501	-7.6391504	-5.3361421	-19.418664	-0.0425108	-7.8447172	-3.1656759	-6.0679327	-10.556895
CVX	-58.4846576	-5.1300688	-26.162301	-2.1361736	4.79306941	5.58167209	-4.66284776	-9.325954	-3.8270769	-24.010344	-7.69315036	182.82012	5.70937755	-27.343532	-10.887693	-21.678134	6.0483314	1.24387119	7.82026021
EBAY	-7.34763541	-26.162012	-3.7537916	0.49330972	-7.636555	-6.4653283	-2.65626606	-8.1805537	-1.5947391	-2.6243743	-5.33614209	5.7093776	69.0710042	2.25253566	5.5056714	-7.7733051	12.353364	-0.8197793	3.39137455
HAL	2.67050431	-3.538545	2.81435319	2.66246593	-2.2087133	-3.1893928	3.202600027	-1.8824772	2.70932061	-2.6580367	-19.4186643	-27.343532	2.25253566	53.2074114	1.76398466	-7.860126	11.8038816	-2.3580031	1.38109009
UPS	-85.4827451	4.89487767	-16.335526	-8.1043493	-0.7307714	2.91767143	-11.8770842	-6.2157694	-7.0306798	-25.296776	-0.04251083	-10.887693	5.5056714	1.76398466	271.148461	-23.142632	-12.254362	-16.513223	-10.012747
DIS	-29.2089776	-44.149367	-19.662714	-26.426792	0.26081097	-7.4939429	-10.0314915	7.76015578	-7.0342774	-6.6434113	-7.8447172	-21.678134	-7.7733051	-7.860126	-23.142632	206.439974	-2.4380158	4.33926778	-7.3337072
WMT	-7.09751351	-9.4116198	-10.502202	12.363801	2.26293038	3.8385262	-3.39386862	-5.2075152	6.33783804	5.82435317	-3.1656759	6.0483314	12.353364	11.8038816	-12.254362	-2.4380158	140.309139	-22.050233	-4.3436092
YUM	-5.78719383	-15.327018	-7.7313618	-28.051928	-3.7229532	14.6925024	-1.43006737	1.68287253	-3.4451469	-2.8705005	-6.06799272	1.2498712	-0.8197793	-2.3580031	-16.513223	4.33926778	-22.050233	107.781768	11.8950647
LUV	-17.098735	-6.2893376	1.77766004	-0.0617814	-3.360766	-1.7450312	-4.13310483	-3.3463475	-2.5943421	1.45332432	-10.5569946	7.8202602	3.39137455	1.38109009	-10.012747	-7.3337072	-4.3436092	11.8950647	55.7579278

7. The fund manager wants to take the expected returns from part (6), and the covariance matrix from part (3), and find the portfolio weights of the 19 stocks that will maximize it's Sharpe ratio. She will the following problem to do this:

$$\max_{\mathbf{w}} r_f + \mathbf{w}'\overline{\mathbf{R}} - \frac{1}{2} A\, \mathbf{w}'\hat{\Omega}_{shrink}\, \mathbf{w}$$

, for $\overline{\mathbf{R}} = \begin{pmatrix} \bar{r}_{MMM} - r_f \\ \bar{r}_{ABT} - r_f \\ \square \\ \bar{r}_{YUM} - r_f \\ \bar{r}_{LUV} - r_f \end{pmatrix}_{19\times 1}$

She will then find the risk-aversion parameter what set's the sum of the weights = 1. That's the portfolio in which she will invest.

Report:

a) The portfolio weights of the 19 stocks
b) The expected return of the portfolio
c) The volatility of the portfolio
d) The Sharpe Ratio of the portfolio with Black Litterman Expected returns, compared to Sharpe Ratio of the market-value-weighted portfolio using R eference Expected returns.

	BL weigthed vector of Expected Return	Optimal weights	Reference Portfolio weights	e	BL return minus risk-free rate r_BL rf
MMM	6.34%	5.09%	4.486%	1	3.34%
ABT	8.75%	3.35%	2.952%	1	5.75%
ACN	7.64%	3.22%	2.833%	1	4.64%
ADBE	7.05%	2.88%	2.533%	1	4.05%
AMZN	15.81%	39.19%	16.981%	1	12.81%
GOOG	10.31%	26.11%	22.997%	1	7.31%
ADM	3.70%	-18.38%	1.005%	1	0.70%
AMAT	7.33%	-12.19%	1.613%	1	4.33%
BAC	9.50%	10.15%	8.944%	1	6.50%
BK	7.40%	2.17%	1.913%	1	4.40%
BHI	6.23%	1.13%	0.996%	1	3.23%
CVX	6.83%	9.00%	7.926%	1	3.83%
EBAY	8.70%	1.66%	1.460%	1	5.70%
HAL	7.02%	1.89%	1.664%	1	4.02%
UPS	5.46%	-9.65%	3.586%	1	2.46%
DIS	7.92%	8.07%	7.110%	1	4.92%
WMT	3.49%	10.01%	8.814%	1	0.49%
YUM	5.04%	1.01%	0.890%	1	2.04%
LUV	9.33%	15.29%	1.296%	1	6.33%
TOTAL		100.00%	100.000%		

	BL Weighted	Ref weighted
E(r)	12%	9%
volatility	17%	13%
Sharpe Ratio	54.03%	48%

Taux = 0.09

Measure lack of confidence in reference view: $(\tau\hat{\Omega}_{shrink})^{-1}$

	MMM	ABT	ACN	ADBE	AMZN	GOOG	ADM	AMAT	BAC	BK	BHI	CVX	EBAY	HAL	UPS	DIS	WMT	YUM	LUV
MMM	1308.132647	-120.936	-91.693051	52.2427327	-32.889367	-1.5592314	-28.1253562	-149.1611	30.5134877	2.24693637	16.0251513	-194.34886	-24.492318	8.90168303	-284.34248	-97.363259	-23.658378	-19.290646	-56.395783
ABT	-120.935397	622.234828	-35.276363	-28.857434	-39.012187	-87.945517	-15.8261851	-18.540385	-4.3687323	-3.3138247	24.4060576	-17.100223	-87.206706	-11.79515	16.3162589	-147.16456	-31.372066	-51.03006	-20.366453
ACN	-91.6930511	-35.276363	593.343244	-37.904385	-21.755414	-75.490824	14.40261326	-6.090693	-21.974847	-47.711729	23.4892846	-87.207671	-12.512639	9.38117731	-54.451755	-65.542379	-35.007339	-25.771206	5.92553346
ADBE	52.24273271	-28.857434	-37.904385	502.298512	-36.418701	-30.766694	-19.6756296	-82.967575	-8.6367814	-8.5137413	14.4850157	-7.3272452	1.64436573	8.87488644	-27.016498	-88.089305	41.2126699	-93.506427	-0.2059381
AMZN	-32.8893663	-39.012187	-21.755414	-36.418701	201.362403	-52.370476	1.193257467	4.41673622	7.3345781	-18.260473	-8.5318205	15.376898	-25.655183	-7.3623776	-2.4359047	0.86936383	7.54310128	-12.403844	-13.26322
GOOG	-1.55923135	-87.945517	-75.490824	-30.766694	-52.370476	376.382894	-2.01144467	-4.5476318	-15.406803	19.5776788	-11.4327127	18.605574	-21.551036	-10.631309	9.72557164	-24.37981	12.7950873	48.375008	-5.8167708
ADM	-28.1253562	-15.826185	14.4026133	-19.67563	1.19325747	-2.0114447	278.5594932	-1.6125849	0.03400078	-34.480738	-12.9089775	-15.542826	-8.8542202	10.6753334	-39.590281	-33.438305	-11.332895	-4.9668812	-13.777016
AMAT	-149.161099	-18.540385	-6.090693	-82.967575	4.41673622	-4.5476318	-1.61258469	254.774391	-16.301779	-32.295979	-11.5718481	-31.086513	-27.268512	-6.2743239	-20.719231	25.8671859	-17.358384	5.60957511	-11.156432
BAC	30.51348771	-4.3687323	-21.974847	-8.6367814	7.3345781	-15.406803	0.034000778	-16.301779	177.548831	-32.064433	11.9338647	-12.756323	-5.3159371	9.0310687	-23.435593	-23.447591	21.1261268	-11.483823	-8.647807
BK	2.246936372	-3.3138247	-47.711729	-8.5137413	-18.260473	19.5776788	-34.4807378	-32.295979	-32.064433	449.218945	-17.4958922	-80.03448	-8.7479144	-8.8601223	-84.322586	-22.144704	19.4145106	-9.568335	4.8444144
BHI	16.0251513	24.4060576	23.4892846	14.4850157	-8.5318205	-11.432713	-12.9089775	-11.571848	11.9338647	-17.495832	243.434834	-25.663835	-17.78114	-64.728881	-0.1417028	-26.149057	-10.552253	-20.226642	-35.189382
CVX	-194.348859	-17.100223	-87.207671	-7.3272452	15.376898	18.6055736	-15.5428259	-31.086513	-12.756323	-80.03448	-25.6638345	609.40041	19.0312585	-91.145108	-36.292331	-72.260447	20.1611047	4.16623729	26.067534
EBAY	-24.492318	-87.206706	-12.512639	1.64436573	-25.655183	-21.551036	-8.8542202	-27.268512	-5.3159371	-8.7479144	-17.7871403	19.031259	230.236681	7.50845219	18.352238	-25.311017	41.1778801	-2.7325398	13.3045818
HAL	8.901683033	-11.79515	9.38117731	8.87488644	-7.3623776	-10.631309	10.67533342	-6.2743239	9.0310687	-8.8601223	-64.7288812	-91.145108	7.50845219	197.358038	5.89394888	-26.20042	33.3662718	-7.8600104	4.60363363
UPS	-284.342484	16.3162589	-54.451755	-27.016498	-2.4359047	9.72557164	-39.5902807	-20.719231	-23.435593	-84.322586	-0.1417027	-36.292331	18.352238	5.89394888	903.828203	-77.142305	-40.847875	-55.044078	-33.375825
DIS	-97.3632586	-147.16456	-65.542379	-88.089305	0.86936383	-24.97381	-33.4383051	25.8671859	-23.447591	-22.144704	-26.1430573	-72.260447	-25.311017	-26.20042	-77.142305	688.333246	-8.1267194	14.4642259	-26.445631
WMT	-23.6583784	-31.372066	-35.007339	41.2126699	7.54310128	12.7950873	-11.3328954	-17.358384	21.1261268	19.4145106	-10.552253	20.161105	41.1778801	33.3662718	-40.847875	-8.1267194	467.69713	-73.500775	-16.478697
YUM	-19.2306461	-51.03006	-25.771206	-93.506427	-12.403844	48.375008	-4.96683123	5.60957511	-11.483823	-9.568335	-20.2266424	4.1662373	-2.7325398	-7.8600104	-55.044078	14.4642259	-73.500775	359.27256	39.6502157
LUV	-56.3957834	-20.366453	5.92553346	-0.2059381	-13.26322	-5.8167708	-13.7770161	-11.156432	-8.647807	4.8444144	-35.189382	26.067534	13.3045818	4.60363363	-33.375825	-26.445631	-16.478697	39.6502157	185.859759

	BL weigthed vector of Expected Return	Optimal weights	Reference Portfolio weights	e	BL return minus risk-free rate r_BL-rf
MMM	6.35%	5.09%	4.486%		
ABT	8.72%	3.35%	2.952%	1	3.35%
ACN	7.63%	3.22%	2.833%	1	5.72%
ADBE	7.06%	2.88%	2.533%	1	4.63%
AMZN	15.43%	37.24%	16.981%	1	4.06%
GOOG	10.24%	26.11%	22.997%	1	12.43%
ADM	3.94%	-16.45%	1.005%	1	7.24%
AMAT	7.50%	-11.01%	1.613%	1	0.94%
BAC	9.53%	10.15%	8.944%	1	4.50%
BK	7.44%	2.17%	1.913%	1	6.53%
BHI	6.21%	1.13%	0.996%	1	4.44%
CVX	6.88%	9.00%	7.926%	1	3.21%
EBAY	8.68%	1.66%	1.460%	1	3.88%
HAL	7.01%	1.89%	1.664%	1	5.68%
UPS	5.48%	-9.54%	3.586%	1	4.01%
DIS	7.92%	8.07%	7.110%	1	2.48%
WMT	3.50%	10.01%	8.814%	1	4.92%
YUM	5.07%	1.01%	0.890%	1	0.50%
LUV	9.08%	14.03%	1.296%	1	2.07%
TOTAL		100.00%	100.000%	1	6.08%

	BL Weighted	Ref weighted
E(r)	12%	9%
volatility	17%	13%
Sharpe Ratio	52.55%	47%