

*VECM 01.sas: Simulation and estimation of the cointegrated model used in section 10.2.*

$$m(t) = m(t-1) + u(t)$$

$$p(1,t) = m(t) + c * q(t)$$

$$p(2,t) = m(t-1)$$

*Run A (high c, high sdu)*

*Simulating 10000 observations with c=1 and std.dev. of u=1*

*Initial data points:*

| Obs | m       | t  | p1      | p2      |
|-----|---------|----|---------|---------|
| 1   | 1.42151 | 1  | 2.42151 | .       |
| 2   | 2.82180 | 2  | 3.82180 | 1.42151 |
| 3   | 3.61264 | 3  | 2.61264 | 2.82180 |
| 4   | 5.43961 | 4  | 4.43961 | 3.61264 |
| 5   | 4.49728 | 5  | 3.49728 | 5.43961 |
| 6   | 3.55960 | 6  | 2.55960 | 4.49728 |
| 7   | 3.10048 | 7  | 2.10048 | 3.55960 |
| 8   | 3.14379 | 8  | 4.14379 | 3.10048 |
| 9   | 1.12207 | 9  | 2.12207 | 3.14379 |
| 10  | 2.21072 | 10 | 1.21072 | 1.12207 |

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*Initial data points:*

*The VARMAX Procedure*

|                            |      |
|----------------------------|------|
| Number of Observations     | 9999 |
| Number of Pairwise Missing | 1    |

| Simple Summary Statistics |           |       |           |                    |             |           |
|---------------------------|-----------|-------|-----------|--------------------|-------------|-----------|
| Variable                  | Type      | N     | Mean      | Standard Deviation | Min         | Max       |
| p1                        | Dependent | 10000 | - 4.14127 | 60.86625           | - 145.93010 | 100.85431 |
| p2                        | Dependent | 9999  | - 4.12181 | 60.86628           | - 145.62152 | 99.85431  |

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|                   |  |
|-------------------|--|
| Type of Model     | VECM(1)                                      |
|                   | with a Restriction on the Deterministic Term |
| Estimation Method | Maximum Likelihood Estimation                |
| Cointegrated Rank | 1  |

| Long- Run<br>Parameter Beta<br>Estimates When<br>RANK=1 |           |
|---|-----------|
| Variable  | 1         |
| p1  | 1.00000   |
| p2  | - 0.99972 |
| 1   | 0.00988   |

| Adjustment<br>Coefficient<br>Alpha Estimates<br>When RANK=1 |           |
|---|-----------|
| Variable  | 1         |
| p1  | - 0.47370 |
| p2  | 0.50547   |

| Parameter Alpha * Beta'<br>Estimates |           |           |           |
|--------------------------------------|-----------|-----------|-----------|
| Variable                             | p1        | p2        | 1         |
| p1                                   | - 0.47370 | 0.47357   | - 0.00468 |
| p2                                   | 0.50547   | - 0.50533 | 0.00499   |

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| Schematic Representation of Parameter Estimates                 |   |     |
|---|---|-----|
| Variable/Lag  | C | AR1 |
| p1  | * | **  |
| p2  | * | **  |
| + is > 2*std error, - is < - 2*stderror, . is between, * is N/A |   |     |

| Model Parameter Estimates |           |           |                |         |         |          |
|---------------------------|-----------|-----------|----------------|---------|---------|----------|
| Equation                  | Parameter | Estimate  | Standard Error | t Value | Pr >  t | Variable |
| D_p1                      | CONST1    | - 0.00468 | 0.00011        |         |         | 1, EC    |
|                           | AR1_1_1   | - 0.47370 | 0.01125        |         |         | p1(t- 1) |
|                           | AR1_1_2   | 0.47357   | 0.01125        |         |         | p2(t- 1) |
| D_p2                      | CONST2    | 0.00499   | 0.00005        |         |         | 1, EC    |
|                           | AR1_2_1   | 0.50547   | 0.00499        |         |         | p1(t- 1) |
|                           | AR1_2_2   | - 0.50533 | 0.00499        |         |         | p2(t- 1) |

| Covariances of Innovations |         |         |
|----------------------------|---------|---------|
| Variable                   | p1      | p2      |
| p1                         | 2.56290 | 0.52173 |
| p2                         | 0.52173 | 0.50436 |

| Information Criteria |          |
|----------------------|----------|
| AICC                 | 0.021017 |
| HQC                  | 0.021993 |
| AIC                  | 0.021017 |
| SBC                  | 0.023902 |
| FPEC                 | 1.021239 |

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| Cross Covariances of Residuals |          |         |         |
|--------------------------------|----------|---------|---------|
| Lag                            | Variable | p1      | p2      |
| 0                              | p1       | 2.56264 | 0.52164 |
|                                | p2       | 0.52164 | 0.50433 |

| Cross Correlations of Residuals |          |         |         |
|---------------------------------|----------|---------|---------|
| Lag                             | Variable | p1      | p2      |
| 0                               | p1       | 1.00000 | 0.45885 |
|                                 | p2       | 0.45885 | 1.00000 |

| Schematic Representation of Cross Correlations of Residuals |    |
|---|----|
| Variable/Lag  | 0  |
| p1  | ++ |
| p2  | ++ |
| + is > 2*std error, - is < - 2*stderror, . is between       |    |

| Univariate Model ANOVA Diagnostics |           |                    |         |        |
|------------------------------------|-----------|--------------------|---------|--------|
| Variable                           | R- Square | Standard Deviation | F Value | Pr > F |
| p1                                 | 0.1507    | 1.60090            | 886.48  | <.0001 |
| p2                                 | 0.5064    | 0.71018            | 5126.48 | <.0001 |

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| Univariate Model White Noise Diagnostics |               |             |            |         |        |
|--|---------------|-------------|------------|---------|--------|
| Variable                                 | Durbin Watson | Normality   |            | ARCH    |        |
|  |               | Chi- Square | Pr > ChiSq | F Value | Pr > F |
| p1                                       | 1.98840       | 56.13       | <.0001     | 26.86   | <.0001 |
| p2                                       | 1.99558       | 101.17      | <.0001     | 0.03    | 0.8651 |

| Univariate Model AR Diagnostics |         |        |         |        |         |        |         |        |
|---------------------------------|---------|--------|---------|--------|---------|--------|---------|--------|
| Variable                        | AR1     |        | AR2     |        | AR3     |        | AR4     |        |
|                                 | F Value | Pr > F | F Value | Pr > F | F Value | Pr > F | F Value | Pr > F |
| p1                              | 0.33    | 0.5638 | 1.03    | 0.3562 | 0.69    | 0.5567 | 0.62    | 0.6478 |
| p2                              | 0.05    | 0.8257 | 1.19    | 0.3037 | 0.79    | 0.5013 | 0.70    | 0.5888 |

| Simple Impulse Response |          |         |         |
|-------------------------|----------|---------|---------|
| Lag                     | Variable | p1      | p2      |
| 1                       | p1       | 0.52630 | 0.47357 |
|                         | p2       | 0.50547 | 0.49467 |
| 2                       | p1       | 0.51637 | 0.48350 |
|                         | p2       | 0.51607 | 0.48407 |
| 3                       | p1       | 0.51616 | 0.48371 |
|                         | p2       | 0.51629 | 0.48385 |
| 4                       | p1       | 0.51615 | 0.48371 |
|                         | p2       | 0.51630 | 0.48385 |
| 5                       | p1       | 0.51615 | 0.48371 |
|                         | p2       | 0.51630 | 0.48385 |
| 6                       | p1       | 0.51615 | 0.48371 |
|                         | p2       | 0.51630 | 0.48385 |
| 7                       | p1       | 0.51615 | 0.48371 |
|                         | p2       | 0.51630 | 0.48385 |

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| Simple Impulse Response |          |         |         |
|-------------------------|----------|---------|---------|
| Lag                     | Variable | p1      | p2      |
| 8                       | p1       | 0.51615 | 0.48371 |
|                         | p2       | 0.51630 | 0.48385 |
| 9                       | p1       | 0.51615 | 0.48371 |
|                         | p2       | 0.51630 | 0.48385 |
| 10                      | p1       | 0.51615 | 0.48371 |
|                         | p2       | 0.51630 | 0.48385 |
| 11                      | p1       | 0.51615 | 0.48371 |
|                         | p2       | 0.51630 | 0.48385 |
| 12                      | p1       | 0.51615 | 0.48371 |
|                         | p2       | 0.51630 | 0.48385 |
| 13                      | p1       | 0.51615 | 0.48371 |
|                         | p2       | 0.51630 | 0.48385 |
| 14                      | p1       | 0.51615 | 0.48371 |
|                         | p2       | 0.51630 | 0.48385 |
| 15                      | p1       | 0.51615 | 0.48371 |
|                         | p2       | 0.51630 | 0.48385 |

### *VECM 01.sas Long- run coefficients*

| Obs | Variable | p1      | p2      |
|-----|----------|---------|---------|
| 1   | p1       | 0.51615 | 0.48371 |
| 2   | p2       | 0.51630 | 0.48385 |

*Note: When all variables in the system refer to the price for the same security, all rows should be equal. If they aren't, try setting nImpulse to a higher value.*



## Variance Decomposition

| Coefficient matrix |           |           |
|--------------------|-----------|-----------|
|                    | p1        | p2        |
| p1                 | 0.5161528 | 0.483713  |
| p2                 | 0.516296  | 0.4838472 |

| Covariance matrix |           |           |
|-------------------|-----------|-----------|
|                   | p1        | p2        |
| p1                | 2.5628966 | 0.5217257 |
| p2                | 0.5217257 | 0.5043591 |

| Correlation matrix |       |       |
|--------------------|-------|-------|
|                    | p1    | p2    |
| p1                 | 1.000 | 0.459 |
| p2                 | 0.459 | 1.000 |

| Purmutation used in decomposition / ordering of variables: |    |
|--|----|
| p1   | p2 |

| Permuted coefficients |           |           |
|-----------------------|-----------|-----------|
|                       | p1        | p2        |
| p1                    | 0.5161528 | 0.483713  |
| p2                    | 0.516296  | 0.4838472 |

| Permuted covariance matrix |           |           |
|----------------------------|-----------|-----------|
|                            | p1        | p2        |
| p1                         | 2.5628966 | 0.5217257 |
| p2                         | 0.5217257 | 0.5043591 |

| Cholesky factor of permuted covariance matrix |           |           |
|---|-----------|-----------|
|   | p1        | p2        |
| p1  | 1.6009049 | 0         |
| p2  | 0.3258942 | 0.6309929 |

Variance Decomposition

| Variance contributions<br>(ordered) |           |           |
|-------------------------------------|-----------|-----------|
|                                     | p1        | p2        |
| p1                                  | 0.9681592 | 0.0931589 |
| p2                                  | 0.9686965 | 0.0932106 |

| Total<br>variance |           |
|-------------------|-----------|
| p1                | 1.0613182 |
| p2                | 1.0619071 |

| Proportional<br>contributions |       |       |
|-------------------------------|-------|-------|
|                               | p1    | p2    |
| p1                            | 0.912 | 0.088 |
| p2                            | 0.912 | 0.088 |

## Variance Decomposition

| Coefficient matrix |           |           |
|--------------------|-----------|-----------|
|                    | p1        | p2        |
| p1                 | 0.5161528 | 0.483713  |
| p2                 | 0.516296  | 0.4838472 |

| Covariance matrix |           |           |
|-------------------|-----------|-----------|
|                   | p1        | p2        |
| p1                | 2.5628966 | 0.5217257 |
| p2                | 0.5217257 | 0.5043591 |

| Correlation matrix |       |       |
|--------------------|-------|-------|
|                    | p1    | p2    |
| p1                 | 1.000 | 0.459 |
| p2                 | 0.459 | 1.000 |

| Purmutation used in decomposition / ordering of variables: |    |
|--|----|
| p2   | p1 |

| Permuted coefficients |           |           |
|-----------------------|-----------|-----------|
|                       | p2        | p1        |
| p1                    | 0.483713  | 0.5161528 |
| p2                    | 0.4838472 | 0.516296  |

| Permuted covariance matrix |           |           |
|----------------------------|-----------|-----------|
|                            | p2        | p1        |
| p2                         | 0.5043591 | 0.5217257 |
| p1                         | 0.5217257 | 2.5628966 |

| Cholesky factor of permuted covariance matrix |           |           |
|---|-----------|-----------|
|   | p2        | p1        |
| p1  | 0.7101825 | 0         |
| p2  | 0.7346362 | 1.4223946 |

Variance Decomposition

| Variance contributions<br>(ordered) |           |           |
|-------------------------------------|-----------|-----------|
|                                     | p2        | p1        |
| p1                                  | 0.5223083 | 0.5390099 |
| p2                                  | 0.5225981 | 0.539309  |

| Total<br>variance |           |
|-------------------|-----------|
| p1                | 1.0613182 |
| p2                | 1.0619071 |

| Proportional<br>contributions |       |       |
|-------------------------------|-------|-------|
|                               | p2    | p1    |
| p1                            | 0.492 | 0.508 |
| p2                            | 0.492 | 0.508 |

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*Simulating 10000 observations with  $c=.1$  and std.dev. of  $u=1$*

*Initial data points:*

| Obs | m       | t  | p1      | p2      |
|-----|---------|----|---------|---------|
| 1   | 1.42151 | 1  | 1.52151 | .       |
| 2   | 2.82180 | 2  | 2.92180 | 1.42151 |
| 3   | 3.61264 | 3  | 3.51264 | 2.82180 |
| 4   | 5.43961 | 4  | 5.33961 | 3.61264 |
| 5   | 4.49728 | 5  | 4.39728 | 5.43961 |
| 6   | 3.55960 | 6  | 3.45960 | 4.49728 |
| 7   | 3.10048 | 7  | 3.00048 | 3.55960 |
| 8   | 3.14379 | 8  | 3.24379 | 3.10048 |
| 9   | 1.12207 | 9  | 1.22207 | 3.14379 |
| 10  | 2.21072 | 10 | 2.11072 | 1.12207 |

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*The VARMAX Procedure*

|                            |      |
|----------------------------|------|
| Number of Observations     | 9999 |
| Number of Pairwise Missing | 1    |

| Simple Summary Statistics |           |       |           |                    |             |          |
|---------------------------|-----------|-------|-----------|--------------------|-------------|----------|
| Variable                  | Type      | N     | Mean      | Standard Deviation | Min         | Max      |
| p1                        | Dependent | 10000 | - 4.13326 | 60.87291           | - 145.52152 | 99.95431 |
| p2                        | Dependent | 9999  | - 4.12181 | 60.86628           | - 145.62152 | 99.85431 |

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### *The VARMAX Procedure*

|                   |  |
|-------------------|--|
| Type of Model     | VECM(1)                                      |
|                   | with a Restriction on the Deterministic Term |
| Estimation Method | Maximum Likelihood Estimation                |
| Cointegrated Rank | 1  |

| Long- Run<br>Parameter Beta<br>Estimates When<br>RANK=1 |           |
|---|-----------|
| Variable  | 1         |
| p1  | 1.00000   |
| p2  | - 0.99997 |
| 1   | 0.00099   |

| Adjustment<br>Coefficient<br>Alpha<br>Estimates When<br>RANK=1 |         |
|--|---------|
| Variable   | 1       |
| p1   | 0.00784 |
| p2   | 0.99013 |

| Parameter Alpha * Beta'<br>Estimates |         |           |         |
|--------------------------------------|---------|-----------|---------|
| Variable                             | p1      | p2        | 1       |
| p1                                   | 0.00784 | - 0.00784 | 0.00001 |
| p2                                   | 0.99013 | - 0.99011 | 0.00098 |

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| Schematic Representation of Parameter Estimates                 |   |     |
|---|---|-----|
| Variable/Lag  | C | AR1 |
| p1  | * | **  |
| p2  | * | **  |
| + is > 2*std error, - is < - 2*stderror, . is between, * is N/A |   |     |

| Model Parameter Estimates |           |           |                |         |         |          |
|---------------------------|-----------|-----------|----------------|---------|---------|----------|
| Equation                  | Parameter | Estimate  | Standard Error | t Value | Pr >  t | Variable |
| D_p1                      | CONST1    | 0.00001   | 0.00001        |         |         | 1, EC    |
|                           | AR1_1_1   | 0.00784   | 0.01005        |         |         | p1(t- 1) |
|                           | AR1_1_2   | - 0.00784 | 0.01005        |         |         | p2(t- 1) |
| D_p2                      | CONST2    | 0.00098   | 0.00000        |         |         | 1, EC    |
|                           | AR1_2_1   | 0.99013   | 0.00098        |         |         | p1(t- 1) |
|                           | AR1_2_2   | - 0.99011 | 0.00098        |         |         | p2(t- 1) |

| Covariances of Innovations |         |         |
|----------------------------|---------|---------|
| Variable                   | p1      | p2      |
| p1                         | 1.04248 | 0.01038 |
| p2                         | 0.01038 | 0.00990 |

| Information Criteria |           |
|----------------------|-----------|
| AICC                 | - 4.58372 |
| HQC                  | - 4.58275 |
| AIC                  | - 4.58373 |
| SBC                  | - 4.58084 |
| FPEC                 | 0.010217  |



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| Cross Covariances of Residuals |          |         |         |
|--------------------------------|----------|---------|---------|
| Lag                            | Variable | p1      | p2      |
| 0                              | p1       | 1.04236 | 0.01038 |
|                                | p2       | 0.01038 | 0.00990 |

| Cross Correlations of Residuals |          |         |         |
|---------------------------------|----------|---------|---------|
| Lag                             | Variable | p1      | p2      |
| 0                               | p1       | 1.00000 | 0.10217 |
|                                 | p2       | 0.10217 | 1.00000 |

| Schematic Representation of Cross Correlations of Residuals |    |
|---|----|
| Variable/Lag  | 0  |
| p1  | ++ |
| p2  | ++ |
| + is > 2*std error, - is < - 2*stderror, . is between       |    |

| Univariate Model ANOVA Diagnostics |           |                    |         |        |
|------------------------------------|-----------|--------------------|---------|--------|
| Variable                           | R- Square | Standard Deviation | F Value | Pr > F |
| p1                                 | 0.0001    | 1.02102            | 0.30    | 0.7443 |
| p2                                 | 0.9903    | 0.09948            | 510955  | <.0001 |

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### *The VARMAX Procedure*

| Univariate Model White Noise Diagnostics |               |             |            |         |        |
|--|---------------|-------------|------------|---------|--------|
| Variable                                 | Durbin Watson | Normality   |            | ARCH    |        |
|  |               | Chi- Square | Pr > ChiSq | F Value | Pr > F |
| p1                                       | 1.99579       | 1.88        | 0.3909     | 0.06    | 0.8116 |
| p2                                       | 1.98871       | 1598.44     | <.0001     | 0.12    | 0.7245 |

| Univariate Model AR Diagnostics |         |        |         |        |         |        |         |        |
|---------------------------------|---------|--------|---------|--------|---------|--------|---------|--------|
| Variable                        | AR1     |        | AR2     |        | AR3     |        | AR4     |        |
|                                 | F Value | Pr > F | F Value | Pr > F | F Value | Pr > F | F Value | Pr > F |
| p1                              | 0.04    | 0.8348 | 0.02    | 0.9786 | 0.03    | 0.9930 | 0.19    | 0.9442 |
| p2                              | 0.31    | 0.5779 | 0.17    | 0.8450 | 0.16    | 0.9245 | 0.23    | 0.9221 |

| Simple Impulse Response |          |         |           |
|-------------------------|----------|---------|-----------|
| Lag                     | Variable | p1      | p2        |
| 1                       | p1       | 1.00784 | - 0.00784 |
|                         | p2       | 0.99013 | 0.00989   |
| 2                       | p1       | 1.00797 | - 0.00797 |
|                         | p2       | 1.00769 | - 0.00766 |
| 3                       | p1       | 1.00798 | - 0.00798 |
|                         | p2       | 1.00800 | - 0.00797 |
| 4                       | p1       | 1.00798 | - 0.00798 |
|                         | p2       | 1.00800 | - 0.00798 |
| 5                       | p1       | 1.00798 | - 0.00798 |
|                         | p2       | 1.00800 | - 0.00798 |
| 6                       | p1       | 1.00798 | - 0.00798 |
|                         | p2       | 1.00800 | - 0.00798 |
| 7                       | p1       | 1.00798 | - 0.00798 |
|                         | p2       | 1.00800 | - 0.00798 |

*VECM 01.sas: Simulation and estimation of the cointegrated model used in section 10.2.*

$$m(t) = m(t-1) + u(t)$$

$$p(1,t) = m(t) + c * q(t)$$

$$p(2,t) = m(t-1)$$

*Run B (low c, high sdu: p1 becomes a better signal of the efficient price)*

*Simulating 10000 observations with  $c=.1$  and std.dev. of  $u=1$*

*Initial data points:*

*The VARMAX Procedure*

| Simple Impulse Response |          |         |           |
|-------------------------|----------|---------|-----------|
| Lag                     | Variable | p1      | p2        |
| 8                       | p1       | 1.00798 | - 0.00798 |
|                         | p2       | 1.00800 | - 0.00798 |
| 9                       | p1       | 1.00798 | - 0.00798 |
|                         | p2       | 1.00800 | - 0.00798 |
| 10                      | p1       | 1.00798 | - 0.00798 |
|                         | p2       | 1.00800 | - 0.00798 |
| 11                      | p1       | 1.00798 | - 0.00798 |
|                         | p2       | 1.00800 | - 0.00798 |
| 12                      | p1       | 1.00798 | - 0.00798 |
|                         | p2       | 1.00800 | - 0.00798 |
| 13                      | p1       | 1.00798 | - 0.00798 |
|                         | p2       | 1.00800 | - 0.00798 |
| 14                      | p1       | 1.00798 | - 0.00798 |
|                         | p2       | 1.00800 | - 0.00798 |
| 15                      | p1       | 1.00798 | - 0.00798 |
|                         | p2       | 1.00800 | - 0.00798 |

### *VECM 01.sas Long- run coefficients*

| Obs | Variable | p1      | p2        |
|-----|----------|---------|-----------|
| 1   | p1       | 1.00798 | - 0.00798 |
| 2   | p2       | 1.00800 | - 0.00798 |

*Note: When all variables in the system refer to the price for the same security, all rows should be equal. If they aren't, try setting nImpulse to a higher value.*

## Variance Decomposition

| Coefficient matrix |           |            |
|--------------------|-----------|------------|
|                    | p1        | p2         |
| p1                 | 1.0079768 | - 0.007977 |
| p2                 | 1.0080044 | - 0.007977 |

| Covariance matrix |           |           |
|-------------------|-----------|-----------|
|                   | p1        | p2        |
| p1                | 1.0424753 | 0.0103783 |
| p2                | 0.0103783 | 0.009896  |

| Correlation matrix |       |       |
|--------------------|-------|-------|
|                    | p1    | p2    |
| p1                 | 1.000 | 0.102 |
| p2                 | 0.102 | 1.000 |

| Purmutation used in decomposition / ordering of variables: |    |
|--|----|
| p1   | p2 |

| Permuted coefficients |           |            |
|-----------------------|-----------|------------|
|                       | p1        | p2         |
| p1                    | 1.0079768 | - 0.007977 |
| p2                    | 1.0080044 | - 0.007977 |

| Permuted covariance matrix |           |           |
|----------------------------|-----------|-----------|
|                            | p1        | p2        |
| p1                         | 1.0424753 | 0.0103783 |
| p2                         | 0.0103783 | 0.009896  |

| Cholesky factor of permuted covariance matrix |           |           |
|---|-----------|-----------|
|   | p1        | p2        |
| p1  | 1.0210168 | 0         |
| p2  | 0.0101647 | 0.0989578 |

Variance Decomposition

| Variance contributions<br>(ordered) |           |            |
|-------------------------------------|-----------|------------|
|                                     | p1        | p2         |
| p1                                  | 1.0590061 | 6.2307E- 7 |
| p2                                  | 1.0590641 | 6.231E- 7  |

| Total<br>variance |           |
|-------------------|-----------|
| p1                | 1.0590067 |
| p2                | 1.0590647 |

| Proportional<br>contributions |       |       |
|-------------------------------|-------|-------|
|                               | p1    | p2    |
| p1                            | 1.000 | 0.000 |
| p2                            | 1.000 | 0.000 |

## Variance Decomposition

| Coefficient matrix |           |            |
|--------------------|-----------|------------|
|                    | p1        | p2         |
| p1                 | 1.0079768 | - 0.007977 |
| p2                 | 1.0080044 | - 0.007977 |

| Covariance matrix |           |           |
|-------------------|-----------|-----------|
|                   | p1        | p2        |
| p1                | 1.0424753 | 0.0103783 |
| p2                | 0.0103783 | 0.009896  |

| Correlation matrix |       |       |
|--------------------|-------|-------|
|                    | p1    | p2    |
| p1                 | 1.000 | 0.102 |
| p2                 | 0.102 | 1.000 |

| Purmutation used in decomposition / ordering of variables: |    |
|--|----|
| p2   | p1 |

| Permuted coefficients |            |           |
|-----------------------|------------|-----------|
|                       | p2         | p1        |
| p1                    | - 0.007977 | 1.0079768 |
| p2                    | - 0.007977 | 1.0080044 |

| Permuted covariance matrix |           |           |
|----------------------------|-----------|-----------|
|                            | p2        | p1        |
| p2                         | 0.009896  | 0.0103783 |
| p1                         | 0.0103783 | 1.0424753 |

| Cholesky factor of permuted covariance matrix |           |           |
|---|-----------|-----------|
|   | p2        | p1        |
| p1  | 0.0994785 | 0         |
| p2  | 0.1043273 | 1.0156728 |

Variance Decomposition

| Variance contributions<br>(ordered) |           |           |
|-------------------------------------|-----------|-----------|
|                                     | p2        | p1        |
| p1                                  | 0.0108923 | 1.0481145 |
| p2                                  | 0.0108929 | 1.0481719 |

| Total<br>variance |           |
|-------------------|-----------|
| p1                | 1.0590067 |
| p2                | 1.0590647 |

| Proportional<br>contributions |       |       |
|-------------------------------|-------|-------|
|                               | p2    | p1    |
| p1                            | 0.010 | 0.990 |
| p2                            | 0.010 | 0.990 |



*VECM 01.sas: Simulation and estimation of the cointegrated model used in section 10.2.*

$$m(t) = m(t-1) + u(t)$$

$$p(1,t) = m(t) + c * q(t)$$

$$p(2,t) = m(t-1)$$

*Run C (high c, low sdu: p2 becomes a better signal of the efficient price)*

*Simulating 10000 observations with c=1 and std.dev. of u=.1*

*Initial data points:*

| Obs | m       | t  | p1       | p2      |
|-----|---------|----|----------|---------|
| 1   | 0.14215 | 1  | 1.14215  | .       |
| 2   | 0.28218 | 2  | 1.28218  | 0.14215 |
| 3   | 0.36126 | 3  | -0.63874 | 0.28218 |
| 4   | 0.54396 | 4  | -0.45604 | 0.36126 |
| 5   | 0.44973 | 5  | -0.55027 | 0.54396 |
| 6   | 0.35596 | 6  | -0.64404 | 0.44973 |
| 7   | 0.31005 | 7  | -0.68995 | 0.35596 |
| 8   | 0.31438 | 8  | 1.31438  | 0.31005 |
| 9   | 0.11221 | 9  | 1.11221  | 0.31438 |
| 10  | 0.22107 | 10 | -0.77893 | 0.11221 |

*VECM 01.sas: Simulation and estimation of the cointegrated model used in section 10.2.*

$$m(t) = m(t-1) + u(t)$$

$$p(1,t) = m(t) + c * q(t)$$

$$p(2,t) = m(t-1)$$

*Run C (high c, low sdu: p2 becomes a better signal of the efficient price)*

*Simulating 10000 observations with c=1 and std.dev. of u=.1*

*Initial data points:*

*The VARMAX Procedure*

|                            |      |
|----------------------------|------|
| Number of Observations     | 9999 |
| Number of Pairwise Missing | 1    |

| Simple Summary Statistics |           |       |          |                    |           |          |
|---------------------------|-----------|-------|----------|--------------------|-----------|----------|
| Variable                  | Type      | N     | Mean     | Standard Deviation | Min       | Max      |
| p1                        | Dependent | 10000 | -0.42214 | 6.15280            | -15.49301 | 10.98543 |
| p2                        | Dependent | 9999  | -0.41218 | 6.08663            | -14.56215 | 9.98543  |

*VECM 01.sas: Simulation and estimation of the cointegrated model used in section 10.2.*

$$m(t) = m(t-1) + u(t)$$

$$p(1,t) = m(t) + c * q(t)$$

$$p(2,t) = m(t-1)$$

*Run C (high c, low sdu: p2 becomes a better signal of the efficient price)*

*Simulating 10000 observations with c=1 and std.dev. of u=.1*

*Initial data points:*

### *The VARMAX Procedure*

|                   |  |
|-------------------|--|
| Type of Model     | VECM(1)                                      |
|                   | with a Restriction on the Deterministic Term |
| Estimation Method | Maximum Likelihood Estimation                |
| Cointegrated Rank | 1  |

| Long- Run<br>Parameter Beta<br>Estimates When<br>RANK=1 |           |
|---|-----------|
| Variable  | 1         |
| p1  | 1.00000   |
| p2  | - 0.99723 |
| 1   | 0.00988   |

| Adjustment<br>Coefficient<br>Alpha Estimates<br>When RANK=1 |           |
|---|-----------|
| Variable  | 1         |
| p1  | - 0.98053 |
| p2  | 0.01030   |

| Parameter Alpha * Beta'<br>Estimates |           |           |           |
|--------------------------------------|-----------|-----------|-----------|
| Variable                             | p1        | p2        | 1         |
| p1                                   | - 0.98053 | 0.97781   | - 0.00969 |
| p2                                   | 0.01030   | - 0.01027 | 0.00010   |

*VECM 01.sas: Simulation and estimation of the cointegrated model used in section 10.2.*

$$m(t) = m(t-1) + u(t)$$

$$p(1,t) = m(t) + c * q(t)$$

$$p(2,t) = m(t-1)$$

*Run C (high c, low sdu: p2 becomes a better signal of the efficient price)*

*Simulating 10000 observations with c=1 and std.dev. of u=.1*

*Initial data points:*

*The VARMAX Procedure*

| Schematic Representation of Parameter Estimates                 |   |     |
|---|---|-----|
| Variable/Lag  | C | AR1 |
| p1  | * | **  |
| p2  | * | **  |
| + is > 2*std error, - is < - 2*stderror, . is between, * is N/A |   |     |

| Model Parameter Estimates |           |           |                |         |         |          |
|---------------------------|-----------|-----------|----------------|---------|---------|----------|
| Equation                  | Parameter | Estimate  | Standard Error | t Value | Pr >  t | Variable |
| D_p1                      | CONST1    | - 0.00969 | 0.00010        |         |         | 1, EC    |
|                           | AR1_1_1   | - 0.98053 | 0.01007        |         |         | p1(t- 1) |
|                           | AR1_1_2   | 0.97781   | 0.01005        |         |         | p2(t- 1) |
| D_p2                      | CONST2    | 0.00010   | 0.00001        |         |         | 1, EC    |
|                           | AR1_2_1   | 0.01030   | 0.00100        |         |         | p1(t- 1) |
|                           | AR1_2_2   | - 0.01027 | 0.00100        |         |         | p2(t- 1) |

| Covariances of Innovations |         |         |
|----------------------------|---------|---------|
| Variable                   | p1      | p2      |
| p1                         | 1.02483 | 0.01241 |
| p2                         | 0.01241 | 0.01011 |

| Information Criteria |           |
|----------------------|-----------|
| AICC                 | - 4.58382 |
| HQC                  | - 4.58284 |
| AIC                  | - 4.58382 |
| SBC                  | - 4.58093 |
| FPEC                 | 0.010216  |

*VECM 01.sas: Simulation and estimation of the cointegrated model used in section 10.2.*

$$m(t) = m(t-1) + u(t)$$

$$p(1,t) = m(t) + c * q(t)$$

$$p(2,t) = m(t-1)$$

*Run C (high c, low sdu: p2 becomes a better signal of the efficient price)*

*Simulating 10000 observations with c=1 and std.dev. of u=.1*

*Initial data points:*

*The VARMAX Procedure*

| Cross Covariances of Residuals |          |         |         |
|--------------------------------|----------|---------|---------|
| Lag                            | Variable | p1      | p2      |
| 0                              | p1       | 1.02482 | 0.01241 |
|                                | p2       | 0.01241 | 0.01011 |

| Cross Correlations of Residuals |          |         |         |
|---------------------------------|----------|---------|---------|
| Lag                             | Variable | p1      | p2      |
| 0                               | p1       | 1.00000 | 0.12194 |
|                                 | p2       | 0.12194 | 1.00000 |

| Schematic Representation of Cross Correlations of Residuals |    |
|---|----|
| Variable/Lag  | 0  |
| p1  | ++ |
| p2  | ++ |
| + is > 2*std error, - is < - 2*stderror, . is between       |    |

| Univariate Model ANOVA Diagnostics |           |                    |         |        |
|------------------------------------|-----------|--------------------|---------|--------|
| Variable                           | R- Square | Standard Deviation | F Value | Pr > F |
| p1                                 | 0.4866    | 1.01234            | 4736.41 | <.0001 |
| p2                                 | 0.0105    | 0.10055            | 52.97   | <.0001 |

*VECM 01.sas: Simulation and estimation of the cointegrated model used in section 10.2.*

$$m(t) = m(t-1) + u(t)$$

$$p(1,t) = m(t) + c * q(t)$$

$$p(2,t) = m(t-1)$$

*Run C (high c, low sdu: p2 becomes a better signal of the efficient price)*

*Simulating 10000 observations with c=1 and std.dev. of u=.1*

*Initial data points:*

*The VARMAX Procedure*

| Univariate Model White Noise Diagnostics |               |             |            |         |        |
|--|---------------|-------------|------------|---------|--------|
| Variable                                 | Durbin Watson | Normality   |            | ARCH    |        |
|  |               | Chi- Square | Pr > ChiSq | F Value | Pr > F |
| p1                                       | 1.99984       | 1533.31     | <.0001     | 3.62    | 0.0573 |
| p2                                       | 1.97205       | 1.52        | 0.4673     | 0.11    | 0.7449 |

| Univariate Model AR Diagnostics |         |        |         |        |         |        |         |        |
|---------------------------------|---------|--------|---------|--------|---------|--------|---------|--------|
| Variable                        | AR1     |        | AR2     |        | AR3     |        | AR4     |        |
|                                 | F Value | Pr > F | F Value | Pr > F | F Value | Pr > F | F Value | Pr > F |
| p1                              | 0.00    | 0.9999 | 0.14    | 0.8693 | 0.17    | 0.9145 | 0.16    | 0.9607 |
| p2                              | 1.93    | 0.1651 | 1.28    | 0.2773 | 0.84    | 0.4726 | 0.71    | 0.5874 |

| Simple Impulse Response |          |         |         |
|-------------------------|----------|---------|---------|
| Lag                     | Variable | p1      | p2      |
| 1                       | p1       | 0.01947 | 0.97781 |
|                         | p2       | 0.01030 | 0.98973 |
| 2                       | p1       | 0.01045 | 0.98681 |
|                         | p2       | 0.01040 | 0.98963 |
| 3                       | p1       | 0.01037 | 0.98689 |
|                         | p2       | 0.01040 | 0.98963 |
| 4                       | p1       | 0.01037 | 0.98689 |
|                         | p2       | 0.01040 | 0.98963 |
| 5                       | p1       | 0.01037 | 0.98689 |
|                         | p2       | 0.01040 | 0.98963 |
| 6                       | p1       | 0.01037 | 0.98689 |
|                         | p2       | 0.01040 | 0.98963 |
| 7                       | p1       | 0.01037 | 0.98689 |
|                         | p2       | 0.01040 | 0.98963 |

*VECM 01.sas: Simulation and estimation of the cointegrated model used in section 10.2.*

$$m(t) = m(t-1) + u(t)$$

$$p(1,t) = m(t) + c * q(t)$$

$$p(2,t) = m(t-1)$$

*Run C (high c, low sdu: p2 becomes a better signal of the efficient price)*

*Simulating 10000 observations with c=1 and std.dev. of u=.1*

*Initial data points:*

*The VARMAX Procedure*

| Simple Impulse Response |          |         |         |
|-------------------------|----------|---------|---------|
| Lag                     | Variable | p1      | p2      |
| 8                       | p1       | 0.01037 | 0.98689 |
|                         | p2       | 0.01040 | 0.98963 |
| 9                       | p1       | 0.01037 | 0.98689 |
|                         | p2       | 0.01040 | 0.98963 |
| 10                      | p1       | 0.01037 | 0.98689 |
|                         | p2       | 0.01040 | 0.98963 |
| 11                      | p1       | 0.01037 | 0.98689 |
|                         | p2       | 0.01040 | 0.98963 |
| 12                      | p1       | 0.01037 | 0.98689 |
|                         | p2       | 0.01040 | 0.98963 |
| 13                      | p1       | 0.01037 | 0.98689 |
|                         | p2       | 0.01040 | 0.98963 |
| 14                      | p1       | 0.01037 | 0.98689 |
|                         | p2       | 0.01040 | 0.98963 |
| 15                      | p1       | 0.01037 | 0.98689 |
|                         | p2       | 0.01040 | 0.98963 |

### *VECM 01.sas Long- run coefficients*

| Obs | Variable | p1      | p2      |
|-----|----------|---------|---------|
| 1   | p1       | 0.01037 | 0.98689 |
| 2   | p2       | 0.01040 | 0.98963 |

*Note: When all variables in the system refer to the price for the same security, all rows should be equal. If they aren't, try setting nImpulse to a higher value.*



## Variance Decomposition

| Coefficient matrix |           |           |
|--------------------|-----------|-----------|
|                    | p1        | p2        |
| p1                 | 0.0103673 | 0.9868897 |
| p2                 | 0.0103961 | 0.9896327 |

| Covariance matrix |           |           |
|-------------------|-----------|-----------|
|                   | p1        | p2        |
| p1                | 1.0248288 | 0.0124141 |
| p2                | 0.0124141 | 0.0101107 |

| Correlation matrix |       |       |
|--------------------|-------|-------|
|                    | p1    | p2    |
| p1                 | 1.000 | 0.122 |
| p2                 | 0.122 | 1.000 |

| Permutation used in decomposition / ordering of variables: |    |
|--|----|
| p1   | p2 |

| Permuted coefficients |           |           |
|-----------------------|-----------|-----------|
|                       | p1        | p2        |
| p1                    | 0.0103673 | 0.9868897 |
| p2                    | 0.0103961 | 0.9896327 |

| Permuted covariance matrix |           |           |
|----------------------------|-----------|-----------|
|                            | p1        | p2        |
| p1                         | 1.0248288 | 0.0124141 |
| p2                         | 0.0124141 | 0.0101107 |

| Cholesky factor of permuted covariance matrix |           |           |
|---|-----------|-----------|
|   | p1        | p2        |
| p1  | 1.0123383 | 0         |
| p2  | 0.0122628 | 0.0998016 |

Variance Decomposition

| Variance contributions<br>(ordered) |           |           |
|-------------------------------------|-----------|-----------|
|                                     | p1        | p2        |
| p1                                  | 0.0005106 | 0.0097009 |
| p2                                  | 0.0005135 | 0.0097549 |

| Total<br>variance |           |
|-------------------|-----------|
| p1                | 0.0102115 |
| p2                | 0.0102684 |

| Proportional<br>contributions |       |       |
|-------------------------------|-------|-------|
|                               | p1    | p2    |
| p1                            | 0.050 | 0.950 |
| p2                            | 0.050 | 0.950 |

## Variance Decomposition

| Coefficient matrix |           |           |
|--------------------|-----------|-----------|
|                    | p1        | p2        |
| p1                 | 0.0103673 | 0.9868897 |
| p2                 | 0.0103961 | 0.9896327 |

| Covariance matrix |           |           |
|-------------------|-----------|-----------|
|                   | p1        | p2        |
| p1                | 1.0248288 | 0.0124141 |
| p2                | 0.0124141 | 0.0101107 |

| Correlation matrix |       |       |
|--------------------|-------|-------|
|                    | p1    | p2    |
| p1                 | 1.000 | 0.122 |
| p2                 | 0.122 | 1.000 |

| Permutation used in decomposition / ordering of variables: |    |
|--|----|
| p2   | p1 |

| Permuted coefficients |           |           |
|-----------------------|-----------|-----------|
|                       | p2        | p1        |
| p1                    | 0.9868897 | 0.0103673 |
| p2                    | 0.9896327 | 0.0103961 |

| Permuted covariance matrix |           |           |
|----------------------------|-----------|-----------|
|                            | p2        | p1        |
| p2                         | 0.0101107 | 0.0124141 |
| p1                         | 0.0124141 | 1.0248288 |

| Cholesky factor of permuted covariance matrix |           |           |
|---|-----------|-----------|
|   | p2        | p1        |
| p1  | 0.1005522 | 0         |
| p2  | 0.123459  | 1.0047819 |

Variance Decomposition

| Variance contributions<br>(ordered) |           |           |
|-------------------------------------|-----------|-----------|
|                                     | p2        | p1        |
| p1                                  | 0.010103  | 0.0001085 |
| p2                                  | 0.0101593 | 0.0001091 |

| Total<br>variance |           |
|-------------------|-----------|
| p1                | 0.0102115 |
| p2                | 0.0102684 |

| Proportional<br>contributions |       |       |
|-------------------------------|-------|-------|
|                               | p2    | p1    |
| p1                            | 0.989 | 0.011 |
| p2                            | 0.989 | 0.011 |