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APPENDIX

MERTON (1987)'S INCOMPLETE INFORMATION MODEL

Merton has derived a two-period model of capital market equilibrium in an environment where each investor knows only about a subset of the available securities by starting with :-

A. The individual investor optimal demands :-

(1) $C_k = I_k (\mu_k + a_k Y + S_k\varepsilon_k)$

where C_k stands for end-of-period cash flow
I_k denotes the amount of physical investment in firm k
μ_k, a_k, S_k are parameters of firm k's production technology
Y denotes a random variable common factor with
$E(Y) = 0$, $E(Y^2) = 1$ and $E(\varepsilon_k) = E(\varepsilon_k / \varepsilon_{1,\dots}\varepsilon_n, Y) = 0$
$k = 1, \dots, n$

Let V_k denote the equilibrium value of firm k at the beginning of the period

$$\therefore \quad R_k = C_k / V_k = I_k\mu_k/V_k + a_k IY/V_k + S_kI_k\varepsilon_k/V_k$$

(2) $R_k = R_k + b_kY + \sigma_k\varepsilon_k$

where $R_k = E(R_k) = I_k\mu_k/V_k$
$b_k = a_k I/V_k$
$\sigma_k = S_kI_k/V_k$

(3) There are two other traded securities : a riskless security with sure return per dollar R (R_{n+2}) and a security that combines the riskless security and a forward contract with cash settlement on the observed factor index Y (R_{n+1}), and assume that both are inside securities.

$R_{n+1} = R_{n+1} + Y$

(4) The utility function of investor j is represented as :

$$U_j = E(R^jW^j) - \delta \text{ Var } (R^jW^j)/2W^j$$

where W^j denotes the value of his initial endowment of shares in the firms evaluated at equilibrium prices
R^j denotes the return per dollar in his portfolio
$\delta > 0$

$j = 1, \ldots, N$

Portfolio return of investor j :

$$R_j = \sum_{k=1}^{n} w_k R_k + w^j_{n+1} R_{n+1}$$

Substituting (2), we get

(5) $$\begin{aligned} R^j &= \Sigma_k^n\, w_k\,(R_k + b_k Y + \sigma_k \varepsilon_k) + w^j_{n+1} R_{n+1} + w^j_{n+1}\, Y \\ &= (\Sigma_k^n\, w_k R_k + w^j_{n+1} R_{n+1}) + (\Sigma_k^n\, w_k b_k + w^j_{n+1}) Y + (\Sigma_k^n\, w_k \sigma_k \varepsilon_k) \\ &= R^j + b^j Y + \sigma^j \varepsilon^j \end{aligned}$$

where (5.1) $b^j = \Sigma_k^n\, w^j_k b_k + w^j_{n+1}$

(5.2) $\sigma^{j2} = \Sigma_k^n\, (w^j_k)^2 \sigma^2_k \quad \Rightarrow \quad \sigma^j = \sqrt{(\Sigma_k^n\, (w^j_k)^2 \sigma^2_k)}$

(5.3) $\varepsilon^j = \Sigma_k^n\, w^j_k \sigma_k \varepsilon_k / \sigma^j$

An expected return on the portfolio of investor j

$$R^j = w_{n+2}\, R + \Sigma_k^{n+1} w_{jk}\, R_k$$

Replace $W_{n+2} = 1 - \Sigma_k^{n+1}\, w^j_k$

$$\begin{aligned} R^j &= R - \Sigma_k^{n+1}\, w^j_k\, R + \Sigma_k^{n+1}\, w^j_k\, R_k \\ &= R - \Sigma_k^n\, w^j_k\, R - w_{n+1}\, R + \Sigma_k^n\, w^j_k\, R_k + w_{n+1}\, R_{n+1} \end{aligned}$$

From (5.1), replace $w^j_{n+1} = b^j - \Sigma_k^n\, w^j_k b_k$

$$R^j = R - \Sigma_k^n\, w^j_k\, R - (b^j - \Sigma_k^n\, w^j_k b_k) R + \Sigma_k^n\, w^j_k\, R_k + (b^j - \Sigma_k^n\, w^j_k b_k) R_{n+1}$$

Rearranging

(6.b) $$\begin{aligned} Rj &= R + b^j\,(R_{n+1} - R) - \Sigma_k^n\, w^j_k\, R + \Sigma_k^n\, w^j_k b_k R + \Sigma_k^n\, w^j_k R_k - \Sigma_k^n\, w^j_k b_k R_{n+1} \\ &= R + b^j (R_{n+1} - R) + \Sigma_k^n\, w^j_k\, (R_k - R - b_k (R_{n+1} - R)) \\ &= R + b^j (R_{n+1} - R) + \Sigma_k^n\, w^j_k\, \Delta_k \end{aligned}$$

where $\Delta_k = R_k - R - b_k (R_{n+1} - R)$

From (5), Variance of Portfolio j

$$Var(R_j) = Var\,(b^j Y + \sigma^j \varepsilon^j) = (b^j)^2 Var\,(Y) + (\sigma^j)^2 Var\,(\varepsilon_j)$$

$$Var\,(Y) = Var(\varepsilon^j) = 1$$

(6.a) $\therefore\ Var(R^j) = (b^j)^2 + (\sigma^j)^2 = (b^j)^2 + \Sigma_k^n\, (w^j_k)^2 \sigma^2_k$

(7) The optimal portfolio choice for the investor :-

$$\text{Max}_{\{b^j,\, w^j\}}\ Z = (\, R^j - (\delta_j/2) Var(R^j) - \Sigma_k^n\, \lambda^j_k w^j_k$$

where λ^j_k is the Kuhn-Tucker multiplier that reflects the constraint that investor j cannot invest in security k if he does not know about security k

$\lambda^j_k = 0$ if $k \in J_j$ and $w_k^j = 0$ if $k \in J_j^c$, the compliment to J_j

from (6.a) and (6.b), the 1st order condition

(8a) $\partial Z/\partial b_j = \partial R^j/\partial b^j - (\delta_j/2)\,\partial Var(R^j)/\partial b_j$
$= R_{n+1} - R - \delta j * 2 * bj/2$
$= R_{n+1} - R - \delta j bj = 0$

$\partial Z/\partial w_k = \partial R^j/\partial w_k - (\delta_j/2)\partial Var(R^j)/\partial W_k - \partial \sum_k^n \lambda^j_k w^j_k/\partial W_k = 0$

consider k = 1

$\partial Z/\partial w_1 = \Delta_1 - \delta j * 2 * w^j_1 \cdot \sigma^2_1/2 - \lambda_1$

(8b) $\therefore\ \partial Z/\partial w_k = \Delta_k - \delta_j w^j_k \sigma^2_k - \lambda_k = 0$ for $k = 1, \ldots, n$

From (8a) and (8b),

Optimal common factor :

(9a) $b^j = (R_{n+1} - R)/\delta_j$

Optimal portfolio weights :

(9b) $w^j_k = \Delta_k/\delta_j \sigma^2_k$ $\quad k \in J_j \ (\lambda^j_k = 0)$

(9c) $w^j_k = 0$ $\quad k \in J_j^c$

(9d) from (5.1) $w^j_{n+1} = b^j - \sum_k^n w^j_k b_k$

We know that $w^j_{n+2} = 1 - \sum_k^{n+1} w^j_k = 1 - \sum_k^n w^j_k - w^j_{n+1}$

Substituting w^j_{n+1} from(9.d),

(9e)
$$\begin{aligned} w^j_{n+2} &= 1 - \sum_k^n w^j_k - (b^j - \sum_k^n w^j_k b_k) \\ &= 1 - b^j - \sum_k^n w^j_k + \sum_k^n w^j_k b_k \\ &= 1 - b^j + \sum_k^n w^j_k (b_k - 1) \end{aligned}$$

From (8b) and (9c), we have that

(10) For $k \in J_j^c$ $\quad \lambda^j_k = \Delta_k = R_k - R - b_k (R_{n+1} - R)$

For $k \in J_j$ $\quad \lambda^j_k = 0$

Since λ^j_k depends on only exogeneous variables, λ^j_k is the same for all investors.

B. Aggregate demand : to determine equilibrium prices and equilibrium return

Assuming $\delta_j = \delta$ and $W^j = W$ for $j = 1, \ldots, N$

(11) From (9.a) : $R_{n+1} = R + \delta b$

Define $D_k \equiv \Sigma_j^N w^j_k W^j$ = the aggregate demand for security k

Follow from (9b), (9c), we have,

(12) $D_k = \Sigma_j^N w^j_k W^j = N_k W \Delta_k / \delta\sigma^2_k$

From (9d) and (9e), we have that

$D_{n+1} = \Sigma_j^N w^j_{n+1} W^j = \Sigma^N b^j W^j - \Sigma_j^N \Sigma_k^n w^j_k W^j b_k$

(note that $b^j = b$ since it depends only on exogeneous variables, see 11)

$$(13) \quad \therefore D_{n+1} = NWb - \Sigma kn\, b_k (\Sigma_j^N w^j_k W^j) = NWb - \Sigma_k^n b_k D_k$$

$$(14) \quad \text{and } D_{n+2} = \Sigma_j^N w^j_{n+2} W^j = \Sigma_j^N [W^j - b^j W^j + \Sigma_k^n w^j_k (b_k - 1) W^j]$$

$$= NW - NWb + \Sigma_k^n (b_k - 1) \Sigma_j^N w^j_k W^j$$

$$= NW - NWb + \Sigma_k^n (b_k - 1) D_k$$

$$= NW - NWb + \Sigma_k^n b_k D_k - \Sigma_k^n D_k$$

$$= NW - (NWb - \Sigma_k^n b_k D_k) - \Sigma_k^n D_k$$

$$= NW - D_{n+1} - \Sigma_k^n D_k$$

$$= NW - \Sigma_k^{n+1} D_k$$

Define $x_k = V_k / \Sigma_j^N W^j = V_k/NW = V_k/M$ where M denotes equilibrium national wealth. We have that, from the equilibrium condition $V_k = D_k$

(15) $x_k = D_k/NW = N_k W \Delta_k / \delta\sigma^2_k NW = N_k/N * \Delta_k \delta\sigma^2_k = q_k \Delta_k / \delta\sigma^2_k$

where $q_k = N_k/N$

from definition of Δ_k in (6.b), we rewrite it as

$R_k = R + b_k(R_{n+1} - R) + \Delta_k$

Substituting $R_{n+1} - R$ from (11) and Δ_k from (15)

The equilibrium expected return on security k,

(16) $R_k \quad = \quad R + b_k b\,\delta + x_k\,\delta\sigma^2_k/q_k$ ************

Substituting R_k, b_k and σ_k as defined in(2) into (6), we have

$I_k\mu_k/V_k = R + (a_k Ik)/V_k * b\delta + x_k\,\delta\,s^2_k\,I^2_k/\,q_k V^2_k$

Multiplying V_k for both sides and substituting $x_k = V_k/M$

$I_k\mu_k \quad = \quad RV_k + a_k Ik\;b\delta + \;V_k\,\delta\,s^2_k\,I^2_k/\,q_k M V_k$

$RV_k \quad = \quad I_k\,(\mu_k - a_k\,b\delta - \delta\,s^2_k\,I_k/\,q_k M)$

The equilibrium relation between the market value of firm k nd the distributional characteristics of its end-of-period cash flow, the relative size of the investor ase who know about the firm, and the aggregate-economy variables :

(17) $V_k \quad = \quad (I_k/R) * (\mu_k - a_k\,b\delta - \delta\,s^2_k\,I_k/\,q_k M)$ ************

C. Effect of incomplete information on equilibrium expected return and asset prices

To find the difference between V^*_k and V_k, first we define V^*_k as

$V^*_k \quad = \quad (I_k/R) * (\mu_k - a_k\,b\delta - \delta\,s^2_k\,I_k/\,M) \qquad ; q_k = 1$

$V^*_k - V_k = (I_k/R) * (\mu_k - a_k\,b\delta - \delta\,s^2_k\,I_k/\,M - \mu_k + a_k\,b\delta + \delta\,s^2_k\,I_k/\,q_k M$

$= (I_k/R) * \{\,\delta\,s^2_k\,I_k/M * (1/q_k - 1)\}$

$= (I_k/R) * \{(1-q_k)\,\delta\,s^2_k\,I_k/q_k M\}$

(18) $V_k \quad = \quad V^*_k - \{\,(1-q_k)\,\delta\,s^2_k\,I_k/q_k\,M\,R\}$ **************

We see that the market value of firm k will always be lower with incomplete information, and the smaller the investor base, the larger the difference.

D. The connection between the effect of incomplete information on equilibrium asset prices and the shadow cost of incomplete diffusion of information among investors

Let $\lambda_k \equiv \sum_j^N \lambda^j k\;/N$ = equilibrium aggregate shadow cost (per investor) for security k, then for individual j who does not know about k, $\lambda_k = \Delta_k$, otherwise $\lambda_k = 0$. We have :-

(19) $\lambda_k = \Sigma_j^N \lambda^j k / N \quad j \in J^c_j$
$= \Delta_k (N-N_k)/N$
$= (1-q_k) \Delta_k$

From (18), substituting from (2) : $s^2_k I_k = \sigma^2_k V^2_k$, from (15) : $V_k / M = x_k$ => $M=V_k/x_k$, and from (19) : $(1-q_k) = \lambda_k/\Delta_k$, we have

$$V_k = V^*_k - \delta(1-q_k)\sigma^2_k V^2_k/q_k MR$$

Recognizing that $\delta x_k \sigma^2_k / q_k = \Delta_k$,

$$\therefore \; V_k = V^*_k - \Delta_k \lambda_k Vk/ \Delta_k R$$

$$V^*_k = V_k + \lambda_k Vk/R$$

$$V^*_k = V_k(1+ \lambda_k/R)Vk$$

(20) $V_k \quad = V^*_k / (1+(\lambda_k/R))$

So, the effect of incomplete information on equilibrium price is similar to applying an additional discount rate.

Substituting $V_k = I_k \mu_k/R_k$ and $V^*_k = I_k \mu_k/R^*_k$ in (20)

$$I_k \mu_k/R_k = I_k \mu_k/\{R^*_k *(1+(\lambda k/R))\}$$

$$R_k = R^*_k(1+ \lambda k/R) = R^*_k + R^*_k \lambda k/R$$

(21) $R_k - R^*_k = \lambda k(R^*_k/R)$

We see that incremental equilibrium expected return on security k is proportional to its shadow cost.

E. The incomplete information model

Applying SML in the incomplete information equation and from (2),

$$Var (R_m) = b^2 + \Sigma_k^n x^2_k \sigma^2_k$$

Define $\beta_k = Cov(R_k,R_m)/ Var (R_m)$

$$\begin{aligned} Cov (R_k,R_m) &= E[(R_k-R_k)(R_m-R_m)] = E[(b_k Y + \sigma_k\varepsilon_k)(bY + \Sigma_k^n x_k\sigma_k\varepsilon_k)] \\ &= E[b_k bY] + E[b_k Y * \Sigma_k^n x_k \sigma_k\varepsilon_k] + E[b\sigma_k\varepsilon_k Y] \\ &\quad + E[\sigma_k\varepsilon_k \cdot \Sigma^n x_k \sigma_k\varepsilon_k] \\ &= b_k b + x_k\sigma^2_k \end{aligned}$$

The second and third terms become zero because $E(\varepsilon_k Y) = 0$ and
$E(Y^2) = E(\varepsilon^2_k) = 1$

(22) $\beta_k = (b_k b + x_k \sigma^2_k) / Var(R_m)$

We can rewrite (16) with results from (19) and (22)

(23)
$$
\begin{aligned}
R_k &= R + b_k b\delta + (\delta x_k\sigma^2_k - \delta x_k\sigma^2_k) + \delta x_k\sigma^2_k/q_k \\
&= R + \delta(b_k b + x_k\sigma^2_k) - \delta x_k\sigma^2_k(1-(1/q_k)) \\
&= R + \delta Var(R_m)\beta_k + (\delta x_k\sigma^2_k/q_k)(1-q_k) \\
&= R + \delta Var(R_m)\beta_k + \Delta_k(1-q_k) \\
&= R + \delta Var(R_m)\beta_k + \Delta_k(1-q_k)
\end{aligned}
$$

multiplying by x_k and summing from k = 1 to n, we have

$$\sum_k^n x_k (R_k - R) = \sum_k^n x_k \delta Var(R_m)\beta_k + \sum_k^n x_k\lambda_k$$

(24) $R_m - R = \delta Var(R_m) \sum^n x_k \beta_k + \lambda_m$

$\delta Var(R_m) = R_m - R - \lambda_m$

Substituting $\delta Var(R_m)$ in (23), then

(25) $R_k - R = \beta_k(R_m - R) + \lambda_k - \beta_k\lambda_m$

$R_k - R = \beta_k(R_m - R) + \alpha_k$ ....

(26) where $\alpha_k = \lambda_k - \beta_k\lambda_m$

We, then, can see that in the world of incomplete information, the market portfolio will not be mean-variance efficient because α_k will not be equal to zero.

Under the incomplete information, the optimal combination of risky assest for a fully-informed investor is given by $w^*_k = \Delta_k / \delta\sigma^2_k$ while the market portfolio holding of the risky asset is $x_k = q_k \Delta_k / \delta\sigma^2_k$. Hence, the difference is

(27) $w^*_k - x_k = \Delta_k/\delta\sigma^2_k - q_k\Delta_k/\delta\sigma^2_k = (\Delta_k/\delta\sigma^2_k)*(1-q_k) = \lambda_k/\delta\sigma^2_k$

BIOGRAPHY

Mrs. Wiyada Sombathirunvong was born on March 2, 1967 in Bangkok. She finished her Bachelor and Master Degree in Business Administration from Assumption University in 1988 and 1991 respectively, and join the Joint Doctoral Progam in Business Administration in 1994. She is currently working as the full-time lecturer at Assumption University.