Academic Notes Series: No. 1

Financial Decisions and Markets: A Course for Asset Pricing

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Work Hard, Study Hard.

Contents

Introduction

This is academic note for Campbell 2017 and this project is beginning from September 10, 2022.

Chapter 1 Choice under Uncertainty

Introduction

❑ *Expected Utility*

This chapter review the basic theory of choice under Uncertainty, ignoring time by assuming that all Uncertainty is resolved at a single future data.

Related Literature:

- Gollier 2001
- Ingersoll 1987

1.1 Expected Utility

Proposition 1.1

- *An ordinal utility function $\Upsilon(.)$ tells you that an agent is indifferent between x and y if $\Upsilon(x) = \Upsilon(y)$ and prefers x to y if $\Upsilon(x) > \Upsilon(y)$.*
- *For any strictly increasing function Θ, the preferences expressed by $\Theta(\Upsilon(.))$ are the same as those expressed by Υ.*

♠

1.2 Risk Aversion

Definition 1.1

An agent is risk averse if she (weakly) dislikes all zero-mean risk at all levels of wealth. That is, for all initial wealth levels W_0 and risk $\widetilde{x}$ with $\mathbf{E}\widetilde{x} = 0$,

$$\mathbf{E}u\left(W_0 + \widetilde{x}\right) \leq u\left(W_0\right) \tag{1.1}$$

♣

1.3 Tractable Utility Function

Chapter 2   Static Portfolio Choice

Chapter 3 Static Equilibrium Asset Pricing

Introduction

- *CAPM*

3.1 The Capital Asset Pricing Model (CAPM)

Some basic assumption:

- All investors are price-takers
- Evaluate portfolios using the means and variances of single-period returns
- Investors have common beliefs about the means, variances, and covariances of returns.
- There are no nontraded assets, taxes, or transactions costs.
- Investors can borrow or lend at a given riskfree interest rate.

Note *The market portfolio is mean-variance efficient.*

3.1.1 Asset Pricing Implication of the Sharpe-Lintner CAPM

An increase in the weight of asset i in portfolio p, ω_i, financed by a decrease in the weight on the riskless asset, affect the mean and variance of the return on portfolio p as follows:

$$\begin{aligned} \overline{R}_p &= \sum_i w_i \left(\overline{R_i} - R_f\right) \\ \frac{dR_p}{dw_i} &= \overline{R_i} - R_f \end{aligned} \tag{3.1}$$

$$\frac{d\operatorname{Var}\left(R_p\right)}{dw_i} = 2\operatorname{Cov}\left(R_i, R_p\right) \tag{3.2}$$

Proof The individual-asset variance and covariances in $Var(R_p)$ are

$$Var(R_p) = 2w_iw_1\operatorname{Cov}\left(R_i, R_1\right) + \cdots + w_i^2\operatorname{Var}\left(R_i\right) + \cdots + 2w_iw_N\operatorname{Cov}\left(R_i, R_N\right)$$

$$\frac{d\operatorname{Var}\left(R_p\right)}{dw_i} = 2w_1\operatorname{Cov}\left(R_i, R_1\right) + \cdots + 2w_i\operatorname{Var}\left(R_i\right) + \cdots + 2w_N\operatorname{Cov}\left(R_i, R_N\right) = 2\operatorname{Cov}\left(R_i, R_p\right) \tag{3.3}$$

The ratio of the effect on mean, (3.1), to the effect on variance, (3.2) in

$$\frac{d\bar{R}_p/dw_i}{d\operatorname{Var}\left(R_p\right)/dw_i} = \frac{\bar{R}_i - R_f}{2\operatorname{Cov}\left(R_i, R_p\right)} \tag{3.4}$$

Proposition 3.1

If portfolio p is mean-variance efficient, this ratio should be the same for all individual assets i.

Proof

$$d\bar{R}_p = \left(\bar{R}_i - R_f\right)dw_i + \left(\bar{R}_j - R_f\right)dw_j \tag{3.5}$$

and

$$d\operatorname{Var}\left(R_p\right) = 2\operatorname{Cov}\left(R_i, R_p\right)dw_i + 2\operatorname{Cov}\left(R_j, R_p\right)dw_j \tag{3.6}$$

Now consider setting dw_j so that the mean portfolio return is unchanged, $d\overline{R_p} = 0$:

$$dw_j = -\frac{\left(\bar{R}_i - R_f\right)}{\left(\bar{R}_j - R_f\right)} dw_i \tag{3.7}$$

The portfolio variance must also be unchanged. We have

$$d\,\mathrm{Var}\left(R_p\right) = \left[2\,\mathrm{Cov}\left(R_i, R_p\right) - 2\,\mathrm{Cov}\left(R_j, R_p\right) \frac{\left(\bar{R}_i - R_f\right)}{\left(\bar{R}_j - R_f\right)}\right] dw_i = 0 \tag{3.8}$$

This requires

$$\frac{\bar{R}_i - R_f}{2\,\mathrm{Cov}\left(R_i, R_p\right)} = \frac{\bar{R}_j - R_f}{2\,\mathrm{Cov}\left(R_j, R_p\right)} \tag{3.9}$$

This equation must hold for all assets j, including the original portfolio itself. Setting $j = p$, we get

$$\frac{\bar{R}_i - R_f}{2\,\mathrm{Cov}\left(R_i, R_p\right)} = \frac{\bar{R}_p - R_f}{2\,\mathrm{Var}\left(R_p\right)} \tag{3.10}$$

or

$$\bar{R}_i - R_f = \frac{\mathrm{Cov}\left(R_i, R_p\right)}{\mathrm{Var}\left(R_p\right)} \left(\bar{R}_p - R_f\right) = \beta_{ip}\left(\bar{R}_p - R_f\right) \tag{3.11}$$

where $\beta_{ip} \equiv \mathrm{Cov}\left(R_i, R_p\right) / \mathrm{Var}\left(R_p\right)$ is the regression coefficient of asset i's return on portfolio p's return.

The market portfolio m is mean-variance efficient. Under the restriction (3.11) describes the market portfolio:

$$\bar{R}_i - R_f = \beta_{im}\left(\bar{R}_m - R_f\right) \tag{3.12}$$

The regression of excess return on the market excess return,

$$R_{it} - R_{ft} = \alpha_i + \beta_{im}\left(R_{mt} - R_{ft}\right) + \epsilon_{it} \tag{3.13}$$

the intercept α_i should be 0 for all assets. α_i is called *Jensen's alpha*.

3.1.2 The Black CAPM

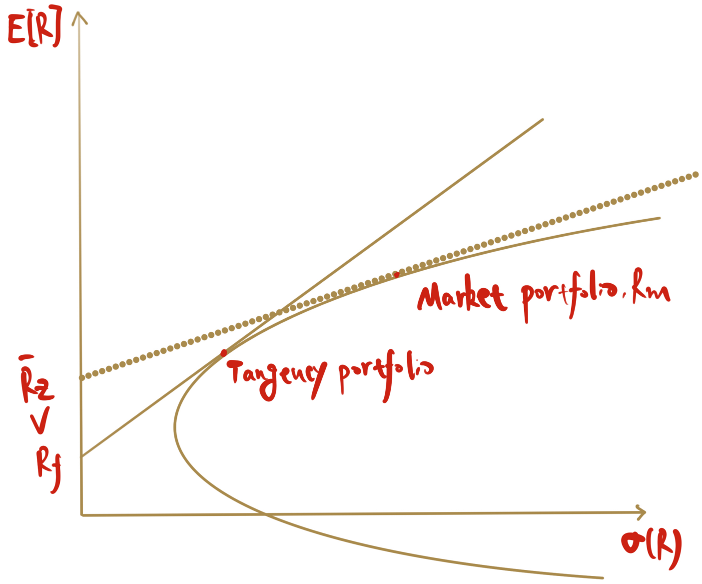

Figure 3.1: The Black (1972) CAPM

3.1.3 Beta Pricing and Portfolio Choice

Problem 3.1 Some Implications of the CAPM. Assume that the Sharpe-Lintner CAPM holds, so the mean-variance efficient frontier consists of combinations of Treasury bills and the market portfolio. Nonetheless, some households make the mistake of holding undiversified portfolios that contain only one stock or a few stocks. (Empirical evidence on such behavior is discussed in Chapter 10.)

1. Show that the Sharpe ratio of any portfolio divided by the Sharpe ratio of the market portfolio equals the correlation of that portfolio with the market portfolio.
2. Suppose the market is made up of identical stocks, each of which has the same market capitalization, the same mean and variance of return, and the same correlation $\rho > 0$, with every other individual stock. Consider the limit as the number of stocks in the market increases. What is the Sharpe ratio of an equally-weighted portfolio that contains N stocks divided by the Sharpe ratio of the market portfolio? Interpret.

Solution

1. *The Sharpe ratio of portfolio p divided by the Sharpe ratio of the market portfolio equals to*

$$\begin{aligned}
&\frac{E\left(R_p-R_f\right)}{\sigma\left(R_p\right)} \Big/ \frac{E\left(R_m-R_f\right)}{\sigma\left(R_m\right)} \\
&=\frac{\beta_{pm} E\left(R_m-R_f\right)}{\sigma\left(R_p\right)} \Big/ \frac{E\left(R_m-R_f\right)}{\sigma\left(R_m\right)} \\
&=\frac{\beta_{pm} \sigma\left(R_m\right)}{\sigma\left(R_p\right)} \\
&=\frac{\operatorname{cov}\left(R_p \cdot R_m\right) \cdot \sigma\left(R_m\right)}{\operatorname{Var}\left(R_m\right) \cdot \sigma\left(R_p\right)} \\
&=\frac{\rho \sigma\left(R_p\right) \sigma\left(R_m\right) \cdot \sigma\left(R_m\right)}{\operatorname{Var}\left(R_m\right) \cdot \sigma\left(R_p\right)} \\
&=\rho
\end{aligned}$$

where ρ is the correlation coefficient between portfolio r_p and r_m.

2. *The equal-weighted portfolio p contains N stocks. So the return and variance of this portfolio is*

$$r_p=\frac{1}{N} r_1+\frac{1}{N} r_2+\ldots+\frac{1}{N} r_N=r$$

$$\begin{aligned}
\sigma_p^2= & \frac{1}{N^2} \sigma^2\left(r_1\right)+\frac{1}{N^2} \sigma^2\left(r_1\right)+\cdots \\
& +2 \frac{1}{N^2} \operatorname{cov}\left(r_1, r_2\right)+\cdots+2 \frac{1}{N^2} \operatorname{cov}\left(r_{N-1}, r_N\right) \\
= & \frac{1}{N} \sigma^2+\frac{2}{N^2} \cdot \frac{N-1}{2} \cdot N \cdot \rho \sigma^2 \\
= & \frac{1}{N} \sigma^2+\frac{N-1}{N} \rho \sigma^2 \\
= & \rho \sigma^2+\frac{1}{N} \sigma^2(1-\rho)
\end{aligned}$$

when $N \rightarrow \infty$, the variance of market portfolio is

$$\sigma_m^2=\rho \sigma^2$$

The Sharpe ratio's ratio is

$$\frac{\sqrt{\rho\sigma^2}}{\sqrt{\rho\sigma^2 + \frac{1}{N}\sigma^2(1-\rho)}}$$
$$= \sqrt{\frac{N\rho}{N\rho + 1 - \rho}}$$

3.2 Arbitrage Pricing and Multifactor Models

3.2.1 Arbitrage Pricing in a Single-Factor Model

$$\begin{aligned} R_{it}^e &= \alpha_i + \beta_{im} R_{mt}^e + \epsilon_{it} \\ \mathrm{E}\left[\epsilon_{it}\epsilon_{jt}\right] &= 0 \\ \mathrm{Cov}\left(R_{it}^e, R_{jt}^e\right) &= \beta_{im}\beta_{jm}\sigma_m^2 \end{aligned}$$

The implication of above assumption is that:

Remark If many assets are available, we should expect α_i typically to be very small in absolute value. This is the *arbitrage pricing theory* of Ross 1976.

Why?

Portfolio of N assets i, the excess return on the portfolio will be

$$R_{pt}^e = \alpha_p + \beta_{pm} R_{mt}^e + \epsilon_{pt}$$

where $\alpha_p = \sum_{j=1}^N w_j\alpha_j, \beta_{pm} = \sum_{j=1}^N w_j\beta_{jm},$ and $\epsilon_{pt} = \sum_{j=1}^N w_j\epsilon_{jt}$.

The variance of ϵ_{pt} will be

$$\mathrm{Var}\left(\epsilon_{pt}\right) = \sum_{j=1}^N w_j^2 \,\mathrm{Var}\left(\epsilon_{jt}\right)$$

which will shrink rapidly with N provided that no single weight w_j is too large.

Suppose that the portfolio has enough stocks, with a small enough weight in each one, that the residual risk $\mathrm{Var}\left(\epsilon_{pt}\right)$ is negligible. We say that the portfolio is **well diversified**. For such a portfolio, we can neglect ϵ_{pt} and write the excess return as

$$R_{pt}^e = \alpha_p + \beta_{pm} R_{mt}^e$$

But we must have $\alpha_p = 0$. If not, there is an arbitrage opportunity: go short β_{pm} units of the market and go long on unit of portfolio p, while funding all positions with riskless borrowing and lending. This delivers a riskless excess return of α_p.

Ross 1976 exploits this insight, showing that $\alpha_p = 0$ for all well-diversified portfolios implies that "almost all" individual assets have α_i very close to zero. Technically, the result is that if idiosyncratic variance of individual assets are bounded above, then

$$\lim_{N\to\infty} \frac{1}{N}\sum_{i=1}^N \alpha_i^2 = 0$$

Proof Consider forming an alpha-weighted portfolio by making dollar investment (this is the weight) of

$$\frac{\alpha_i}{\sqrt{N\sum_{i=1}^N \alpha_i^2}}$$

So the payoff on this portfolios is

$$\frac{\sum_{i=1}^{N} \alpha_i R_{it}}{\sqrt{N \sum_{i=1}^{N} \alpha_i^2}} = \frac{\sum_{i=1}^{N} \alpha_i \left(R_{ft} + \alpha_i + \beta_{im} R_{mt}^e + \epsilon_{it}\right)}{\sqrt{N \sum_{i=1}^{N} \alpha_i^2}}$$

We make two additional assumption:

1.
$$\lim_{N \to \infty} \frac{\sum_{i=1}^{N} \alpha_i}{\sqrt{N \sum_{i=1}^{N} \alpha_i^2}} = 0$$

2.
$$\lim_{N \to \infty} \frac{\sum_{i=1}^{N} \alpha_i \beta_{im}}{\sqrt{N \sum_{i=1}^{N} \alpha_i^2}} = 0$$

In other words, that as the number of assets increase ($N \to \infty$), the total initial dollar investment is zero, and the portfolio has a zero beta with market.

So the limiting payoff on the alpha-weighted portfolio has only 2 components:

$$\lim_{N \to \infty} \frac{\sum_{i=1}^{N} \alpha_i R_{it}}{\sqrt{N \sum_{i=1}^{N} \alpha_i^2}} = \sqrt{\frac{\sum_{i=1}^{N} \alpha_i^2}{N}} + \frac{\sum_{i=1}^{N} \alpha_i \epsilon_{it}}{\sqrt{N \sum_{i=1}^{N} \alpha_i^2}} \tag{3.14}$$

The variance of the payoff in equation (3.14) is

$$\frac{\mathrm{Var}\left(\sum_{i=1}^{N} \alpha_i \epsilon_{it}\right)}{N \sum_{i=1}^{N} \alpha_i^2} = \frac{\sum_{i=1}^{N} \alpha_i^2 \sigma_i^2}{N \sum_{i=1}^{N} \alpha_i^2} = 0$$

So the first term of equation (3.14) should equal to zero, which is

$$\lim_{N \to \infty} \frac{1}{N} \sum_{i=1}^{N} \alpha_i^2 = 0$$

3.2.2 Multifactor Models

3.3 Empirical Evidence

3.3.1 Test Methodology

3.3.1.1 Time-Series Approach

$$R_{it} - R_{ft} = \alpha_i + \beta_{im}(R_{mt} - R_{ft}) + \epsilon_{it} \tag{3.15}$$

The null hypothesis is that $\alpha = 0$.

Note *The challenge is to test it jointly for a set of N assets.*

3.3.1.2 Cross-Section Approach

3.3.1.3 Fama-MacBeth Approach

3.3.2 The CAPM and the Cross-Section of Stock Returns

- **Beta**

- **Size** Banz 1981 found that small market capitalization firms tend to have higher average return than their betas justify. But there are several reasons for "size effect" commanding less attention:
  1. Large stocks outperformed small ones during the 1990s and part of 2000s.
  2. Keim 1983, and Reinganum 1983 point out that size effect was concentrated in January, which is a seasonal anomaly that began to disappear shortly after it was publicized.
  3. Academic research preferred to normalize market capitalization by other measures of the scale of the firm.
  4. However, Asness et al. 2018 found size effect still exist when controlling firm's quality.
- **Value**
- **Momentum**
- **Post-event drift**
- **Turnover and volatility**
- **Insider trading**
- **Growth of the firm**. Total asset growth
- **Earning quality**
- **Profitability**

3.4 Solution and Further Problems

Problem 3.2 Appraisal Ratio. Consider a frictionless one-period economy with multiple risky assets and a riskfree asset with return R_f. Let R_p denote the return to the risky portfolio of an agent who trades off the mean against the variance of his (total) portfolio return, $\theta R_p + (1-\theta)R_f$, where θ denotes the share of initial wealth invested in risky assets.

Suppose the investor is in the process of constructing his optimal portfolio and has a candidate or "benchmark" portfolio of risky assets with return R_b that is optimal with respect to existing assets. But he becomes aware of a new investment opportunity (asset) with return R_n and wishes to adjust his portfolio in order to take advantage of this new opportunity.

- Explain intuitively why a portfolio adjustment policy that uses the Sharpe ratio of the existing portfolio, $SR_b = \mathbf{E}[R_b - R_f]/\sigma_b$, and the Sharpe ratio of the new investment, $SR_n = \mathbf{E}[R_n - R_f]/\sigma_n$, as sufficient statistics for the adjustment is not optimal. Here, $\sigma_b^2 = \mathrm{Var}(R^b)$ and $\sigma_n^2 = \mathrm{Var}(R_n)$.
- Let ω denote the optimal weight of the risky portfolio on the new asset, so that $\omega R_n + (1-\omega)R_b$. Explain why the agent chooses ω so as to maximize the Sharpe ratio of his risky portfolio, where the Sharpe ratio $SR_p = \mathbf{E}[R_p - R_f]/\sigma_p$, with $\sigma_p^2 = \mathrm{Var}(R_p)$. Show that
$$w = \frac{\mathrm{E}\left[R_n - R_f\right]\sigma_b^2 - \mathrm{E}\left[R_b - R_f\right]\sigma_{nb}}{\mathrm{E}\left[R_n - R_f\right]\sigma_b^2 + \mathrm{E}\left[R_b - R_f\right]\sigma_n^2 - \left(\mathrm{E}\left[R_n - R_f\right] + \mathrm{E}\left[R_b - R_f\right]\right)\sigma_{nb}}$$
where $\sigma_{nb} = \mathrm{Cov}\left(R_n, R_b\right)$.
- Suppose the investor believes that the return to the new asset is given by
$$R_n - R_f = \alpha + \beta\left(R_b - R_f\right) + \varepsilon$$
where α and β are constants, ε has mean zero and variance σ_ε^2, and $\mathbf{E}[\varepsilon R_b] = 0$.
  1. Show that
$$w = \frac{\bar{w}}{1 + (1-\beta)\bar{w}}, \quad \text{where } \bar{w} \equiv \frac{\alpha/\sigma_\varepsilon^2}{\mathrm{E}\left[R_b - R_f\right]/\sigma_b^2}$$

Explain intuitively why ω is increasing in α and decreasing in σ_ε^2. Assuming $\alpha > 0$, why is it increasing in β?

2. Show that

$$SR_p^2 = SR_b^2 + AR_n^2$$

where $AR_n \equiv \alpha/\sigma_\varepsilon$ is the appraisal ratio of the new asset (Treynor and Black 1973).
How is the appraisal ratio different from and how is it similar to the Sharpe ratio? Why is it that the former performance measure captures the improvement in portfolio efficiency due to the new investment? Why does the formula involve the square of the appraisal ratio? Does the implied formula for AR_n^2 remind you of a test statistic? Explain.

- The Treynor and Black 1973 model is a classic model of active portfolio management. The authors argue that portfolio construction should begin with a passive benchmark (the market portfolio), and investors with superior information about certain assets (nonzero perceived alphas) should adjust their exposure to these assets (the active part of their portfolio) based on a generalization of the simple algorithm discussed in part (b). How is this approach similar to the Black and Litterman 1992 model of portfolio construction?

Solution

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Chapter 4 The Stochastic Discount Factor

Chapter 5 Present Value Relations

Introduction

- *EMH*

5.1 Market Efficiency

5.2 Present Value Models with Constant Discount Rates

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Appendix A Nothing