Economic Foundations and Applications of Risk

Part B. Applications

Chapter 4: Optimal Portfolio Choice

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Syllabus

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4.1 Introduction

- One of the most archetypal decisions under risk is the **investment decision.**
- In this chapter, we will study a simple **portfolio choice model,** where an individual has to choose between a secure and a risky asset (4.2).
- We will concentrate on the **comparative static properties** of the investment decisions with respect to ...
  - ... the individual's **risk aversion** (4.3),
  - ... the **riskiness of the risky asset** (4.4),
  - ... an individual's **initial income** (4.5), and
  - ... the **return of the secure asset** (4.6).

4.2 Main model

Setup

- An individual can invest her initial wealth, w_0, in a **riskless asset** that pays out $(1+i)$ with certainty ...
- ... and a **risky asset** with payout $(1+x)$ (where $\mu \equiv E[x]$).
- Let m denote the amount invested in the risk-free asset and a the sum invested in the risky asset.
- **Final wealth,** w, is then given by $w = m(1+i) + a(1+x)$.
- The **maximization problem** takes the following form:

$$\max_{a,m} \mathrm{E}[u(m(1+i) + a(1+x))] \qquad \text{s.t. } m + a \leq w_0$$

$$m = w_0 - a$$

$$W = \underbrace{(w_0 - a)}_{m}(1+i) + a(1+x)$$

$$w_0(1+i) - \cancel{a} - ai + \cancel{a} + ax$$

$$w_0(1+i) + a(x-i)$$

Optimal portfolio choice

- Since the constraint will bind in the optimum, we can rewrite:

$E(U(W(a)))$

$$\max_a E\left[u\left(\underbrace{w_0(1+i)+a(x-i)}_{W}\right)\right]$$

- The **first-order condition (FOC)** reads:

$$\frac{\partial \mathrm{E}u}{\partial a} = \overbrace{\mathrm{E}[u'(w_0(1+i)+a^*(x-i))}^{\frac{\partial EU}{\partial W}}\overbrace{(x-i)]}^{\frac{\partial W}{\partial a}} \overset{!}{=} 0$$

≈ 0

- The **second-order condition (SOC)** reads:

$$\frac{\partial^2 \mathrm{E}u}{\partial a^2} = \mathrm{E}[\underbrace{u''(\cdot)}_{\ominus}\underbrace{(x-i)^2}_{\oplus}] \overset{!}{<} 0$$

if risk averse

- The SOC is satisfied for risk averse individuals ($u'' < 0$).

Important result

- Hypothetical question: Can it be optimal that $a^* = 0$?

$$
\begin{aligned}
\frac{\partial \mathrm{E}u}{\partial a}\Big|_{a=0} &= \mathrm{E}\big[u'\overbrace{(w_0(1+i))}^{\text{const.}}(\tilde{x}-i)\big] \\
&= u'(w_0(1+i))\mathrm{E}[\tilde{x}-i] \\
&= \underbrace{u'(w_0(1+i))}_{+}\underbrace{(\mu-i)}_{E(x)}
\end{aligned}
$$

$E(c \cdot \tilde{x}) = c \cdot E(\tilde{x})$

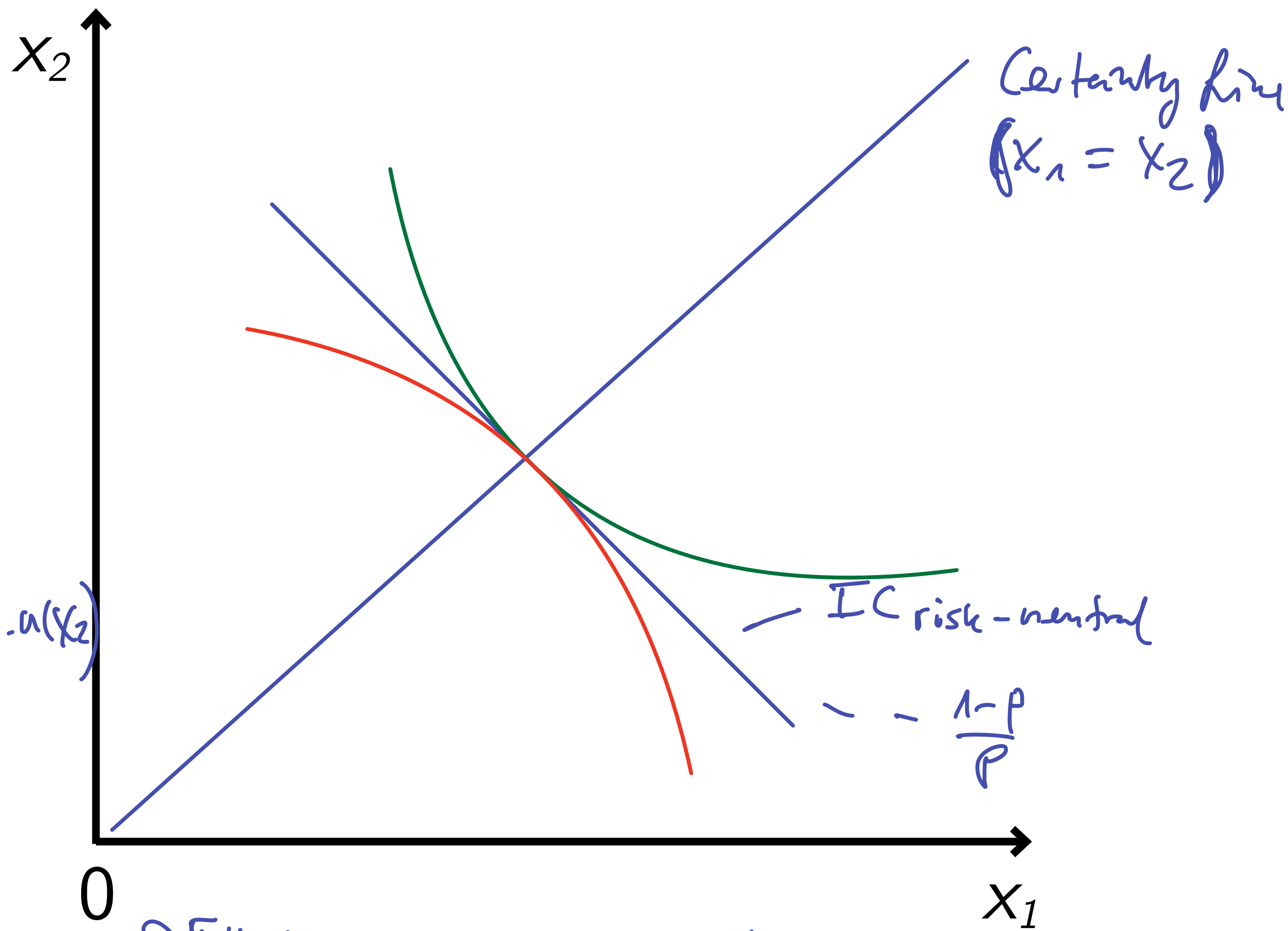
$E(\tilde{x} \pm c) = E(\tilde{x}) \pm c$

$E(\tilde{x}) - E(i)$

$(\mu - i)$

- Since $u' > 0$, it follows that
  - $a^* > 0 \iff \mu > i$, and
  - $a^* = 0 \iff \mu \leq i$ (If restricting a^* to non-negative values.)
- This is a **strong result:** Any risk-averse individual will (to some degree) partake in a risky project if the expected return from doing so is strictly larger than i.
- Intuition: At the certainty level, risk costs are second-order.

Graph: States of the World diagram



$EU = (1-p)\cdot u(x_1) + p\cdot u(x_2)$

MRS: $\left.\frac{dx_2}{dx_1}\right|_{U=const} = -\frac{\partial EU/\partial x_1}{\partial EU/\partial x_2} = -\left.\frac{(1-p)\cdot u'(x_1)}{p\cdot u'(x_2)}\right|_{x_1=x_2} = -\frac{(1-p)}{p}\cdot\cancel{\frac{u'(x_2)}{u'(x_2)}} = -\frac{1-p}{p}$

A refresher: Implicit function theorem

- For the rest of this chapter, we will look at the **comparative static properties** of optimal portfolio choice
- For this, we need the **implicit function theorem (IFT).**

Lemma 4.1: Implicit function theorem

- Let $f(x, y)$ be a continuously differentiable function with $f(x, y) = 0$ and $\frac{\partial f}{\partial x}|_{x,y} \neq 0$.
- Then, the following equality will hold:

$$\frac{dx}{dy} = -\frac{\frac{\partial f(x,y)}{\partial y}}{\frac{\partial f(x,y)}{\partial x}}$$

Intuition of comparative static results

- However, the **proofs** (for a general utility function) are **technically very involved** and go beyond what is expected of you in this blocked course
- This is why, it will be **sufficient to discuss the intuition** of the comparative static results
- So **let's start discussing:** What do you believe to be true?
  - As risk aversion increases, a^* ↓
  - As the riskiness of the risky asset increases, a^* ↓
  - As initial income (w_0) increases, a^* ↑ iff DARA
    → if CARA
    ↓ if IARA
  - As the return of the safe asset (i) increases, a^*
- We will verify a few of these results in an exercise for $u(x) = \ln(x)$

$$\frac{\partial a}{\partial i} = \underset{\ominus}{SE} + \underset{\oplus \text{ if DARA}}{IE}$$

↳ $i \uparrow$ → disposable income $\uparrow$

↳ if DARA → $a \uparrow$

Overall Effect is typically negative