Ambiguity Aversion in Standard and Extended Ellsberg Frameworks: α-Maxmin versus Maxmin Preferences

Claudia Ravanelli
Center for Finance and Insurance
Department of Banking and Finance, University of Zurich

with *Gregor Svindland*, LMU München

7th General AMaMeF and Swissquote Conference 2015
SwissTech Convention Center, EPFL, Switzerland
September 7-10, 2015

Outline

Motivation

Maxmin and α-maxmin expected utility models

Market Model

Standard Ellsberg framework

Extended Ellsberg frameworks

Outline

Motivation

Maxmin and α-maxmin expected utility models

Market Model

Standard Ellsberg framework

Extended Ellsberg frameworks

Ambiguity

Two kinds of uncertainty (distinction due to Knight (1921))

1. *Risk*: *all events are associated* with obvious *probability assignments*
2. *Ambiguity* or *Knightian uncertainty*: *some events do not have an obvious, unanimously agreeable, probability assignment*

Facing *ambiguity*, decision makers may adjust their behaviour:

- ambiguity averse: take action robust to ambiguity
- ambiguity seeking: take action exposed to ambiguity

Ambiguity sensitive preferences and market phenomena

1. Experimental evidence:

   majority of subjects are *ambiguity averse*, *a few ambiguity seeking*

2. Theoretical financial market models:

   different attitude towards ambiguity are consistent with *non participation*, *portfolio inertia*, and *excess of volatility of assets returns*

$\Rightarrow$

Investors' preferences: *heterogeneous*, well approximated by SEU *and* ambiguity averse preferences with *different* degree of ambiguity aversion

Ambiguity sensitive behaviors are *inconsistent with SEU theory* $\Rightarrow$

Several models to model ambiguity sensitive preferences

We focus on: *maxmin* expected utility and α-*maxmin* expected utility

Outline

Motivation

Maxmin and α-maxmin expected utility models

Market Model

Standard Ellsberg framework

Extended Ellsberg frameworks

Maxmin expected utility model Gilboa–Schmeidler (1989)

maxmin *pioneering and workhorse* model to study the implications of ambiguity aversion in portfolio choice and equilibrium asset prices

$$U(w) = \min_{\pi \in \mathcal{C}} \sum_{\sigma \in S} u(w_\sigma)\, \pi_\sigma$$

- $\mathcal{C}$ set of priors *determined jointly by agent's information and personal taste*
- *ambiguity averse attitude*: portfolio w evaluated by its minimum expected utility

$\rightarrow$ tractable optimization problems: u concave $\Rightarrow$ U concave

$\rightarrow$ information and attitude to ambiguity *inextricably intertwined* in $\mathcal{C}$: smaller sets may reflect both better information and less averse ambiguity attitude

α-maxmin expected utility model

α-maxmin expected utility (α-MEU) model

$$U(w) = \alpha \min_{\pi \in \mathcal{C}} \sum_{\sigma \in S} u(w_\sigma)\,\pi_\sigma + (1-\alpha) \max_{\pi \in \mathcal{C}} \sum_{\sigma \in S} u(w_\sigma)\,\pi_\sigma, \quad \alpha \in [0,1]$$

generalizes the *maxmin* model ($\alpha = 1$)

→ large spectrum of ambiguity attitude: from the ambiguity *aversion* of the *maxmin* model to ambiguity *seeking* of the *maxmax* model ($\alpha = 0$)

→ given $\mathcal{C} = \mathcal{C}_{\max} = \{$all priors consistent with available information$\}$ the parameter α is a measure the degree of agent's ambiguity aversion: *the greater* α *the more ambiguity averse the agent's preferences*

→ portfolio optimization problem not concave: U in general *not concave* despite u concave

→ no axiomatization of the model

α-MEU model in the literature

α-MEU model increasingly popular

- *decision theory*
- *Experimental financial economics*

  α-MEU for the estimation of the agent's degree of ambiguity aversion/seeking; *Ahn et al.* (2011)
- *Theoretical financial economics*: just a few

  competitive financial market with SEU and α-MEU agents; *Bossaerts, Ghirardato Guarnaschelli and Zame* (2010) (BGGZ)

Setting of the above papers: *Standard Ellsberg framework BUT* in this setting ambiguity averse α-MEU preferences *reduce to* maxmin preference!

Goal of this paper

Financial economics point of view:

derive the implications of α-MEU model for

- *portfolio choices*
- *equilibrium asset prices*

as a function of the degree of ambiguity aversion $\alpha \in (0, 1)$

This allows to

- provide criteria to estimate's agent's ambiguity aversion
- understand the α-*MEU* model and the preferences that it represents
- contrast α-*MEU* and *maxmin* model implications

Outline

Motivation

Maxmin and α-maxmin expected utility models

Market Model

Standard Ellsberg framework

Extended Ellsberg frameworks

Setting

Arrow–Debreu complete market with two dates: $t = 0$ and $t = 1$ embedded in an Ellsberg framework

· S finite state space with $m + l$ states of the economy at $t = 1$ states correspond to draws from Ellsberg (1961) urn:

$$m \geq 0 \text{ \textit{risky} states and } l \geq 2 \text{ \textit{ambiguous} states}$$

· At $t = 0$ investors face *risk* and *ambiguity*:

neither know which state will realize at $t = 1$ (*risk*), nor what is probability of some states (*ambiguity*)

Setting (cont.)

· $\forall \omega \in S$, $\exists$ Arrow security traded in the market $\Rightarrow$ agents can form:

- *unambiguous* portfolio, i.e. portfolio with no exposure to ambiguity:

$$w = (\underbrace{w_R^1, \dots, w_R^m}_{m \text{ risky states}}, \underbrace{\tilde{w}, \dots, \tilde{w}}_{l \text{ ambiguous states}})$$

- *ambiguous* portfolios, i.e. portfolios exposed to ambiguity:

$$w = (\underbrace{w_R^1, \dots, w_R^m}_{m \text{ risky states}}, \underbrace{w^{m+1}, \dots, w^{m+l}}_{l \text{ ambiguous states}})$$

· u (risk aversion) *strictly concave and increasing and differentiable*

Outline

Motivation

Maxmin and α-maxmin expected utility models

Market Model

Standard Ellsberg framework

Extended Ellsberg frameworks

Standard Ellsberg framework ($m = 1$, $l = 2$)

$S = \{R, G, B\}$

$m = 1$ risky state, R, with known probability $\pi_R \in (0, 1)$
$l = 2$ ambiguous states, G and B, with unknown probabilities

Any set of priors consistent with the Ellsberg framework reads

$$\mathcal{D}_{a,b} = \{(\pi_R, q, 1 - q - \pi_R) : q \in [a, b]\}$$

for some given a and b, $0 \leq a \leq b \leq 1 - \pi_R \quad \Rightarrow$

Any α-MEU utility with $\alpha \in [0, 1]$ reads

$$\begin{aligned} U(w) = \pi_R u(w_R) \quad & + \quad \alpha \min_{q\in[a,b]} [qu(w_G) + (1 - q - \pi_R)u(w_B)] \\ & + \quad (1 - \alpha) \max_{q\in[a,b]} [q\, u(w_G) + (1 - q - \pi_R)\, u(w_B)] \end{aligned}$$

w is a state dependent portfolio $w = (w_R, w_G, w_B) \in \mathbb{R}^3$

Main findings in the Standard Ellsberg framework

- Equivalence result: α-*MEU* preferences are equivalent to:
  - *maxmin* preferences when $\alpha > 1/2$
  - *SEU* preferences when $\alpha = 1/2$
  - *maxmax* preferences when $\alpha < 1/2$

- Ambiguity aversion implications on equilibrium asset prices: *ambiguity aversion does not wash out in equilibrium*

Equivalence result

When $\alpha > 1/2$:

any α-MEU utility, $\alpha > 1/2$, set of prior $\mathcal{D}_{a,b}$ is equal to a *unique maxmin* utility with set of priors $\mathcal{C}$ *smaller* than $\mathcal{D}_{a,b}$, and univocally characterized by α and $\mathcal{D}_{a,b}$:

$$U(w) = \min_{q \in [c,d]} \left[\pi_R\, u(w_R) + q\, u(w_G) + (1 - q - \pi_R)\, u(w_B)\right]$$

$$\mathcal{C} = \{(\pi_R, q, 1 - q - \pi_R) : q \in [c, d]\} \subset \mathcal{D}_{a,b}$$
$$c := \alpha\, a + (1 - \alpha) b \text{ and } d := (1 - \alpha) a + \alpha\, b$$

decreasing α from 1 to $1/2$ in the α-MEU representation, is equivalent to *shrinking symmetrically* $\mathcal{C}$ in the corresponding maxmin representation

Equivalence result (cont.)

Implications of the equivalence result:

- Standard Ellsberg framework is *not* the right setting to study the α-MEU model: α-MEU preferences cannot be distinguished from maxmin, or maxmax or SEU preferences

- Experimental studies:
  - it *clarifies* recent works in the standard Ellsberg framework that uses the α-MEU as generalization of the maxmin model to document a substantial heterogeneity in aversion to ambiguity; e.g. BGGZ (2010), and Ahn *et al.* (2011)
  - *Same conclusion by using maxmin* varying the size of the set of priors instead of α to measure the degrees of aversion to ambiguity

Implications of ambiguity aversion on equilibrium asset prices

Financial market populated by $L + M$ investors

- L with SEU preferences with prior $\pi = (\pi_R, \pi_G, \pi_B)$
- M with ambiguity averse preferences (maxmin or equivalently α-MEU $\alpha > 1/2$)

1. we derive *equilibrium asset prices* and show through which channels ambiguity aversion impacts equilibrium asset prices
2. *theoretical* equilibrium asset prices *perfectly match* the *experimental* findings in BGGZ (2010)

$\Rightarrow$ *Ambiguity aversion does not wash out in equilibrium*

Portfolio choice of SEU and ambiguity averse agents

Well known facts:

- SEU agent optimal portfolio $y = (y_R, y_G, y_B)$ state dependent wealth is ranked opposite to the state-price/state-probability ratios:

$$y_\sigma > y_\nu \Leftrightarrow \frac{p_\sigma}{\pi_\sigma} < \frac{p_\nu}{\pi_\nu}, \quad \sigma, \nu \in \{R, B, G\}$$

- ambiguity averse agent with utility

$$U(w) = \pi_R\, u(w_R) + \min_{q \in [c,d]} (q\, u(w_G) + (1 - q - \pi_R)\, u(w_B)),$$

optimal portfolio $w = (w_R, w_G, w_B)$:

$$\begin{cases} w_G > w_B & \Leftrightarrow \quad \frac{p_G}{p_B} < \frac{c}{1-\pi_R-c} \\ w_G < w_B & \Leftrightarrow \quad \frac{p_G}{p_B} > \frac{d}{1-\pi_R-d} \\ w_G = w_B \text{ (unambiguous)} & \Leftrightarrow \quad \frac{p_G}{p_B} \in \left[\frac{c}{1-\pi_R-c}, \frac{d}{1-\pi_R-d}\right] \end{cases}$$

The larger the set of priors, the more likely $w_B = w_G$

Market equilibrium: theoretical findings

State-price/state-probability ratios in equilibrium depend on the market total endowment $W = (W_R, W_G, W_B)$

Case of interest:

- $W_G \neq W_B$, for instance $W_G > W_B$
- ambiguity averse agents take *unambiguous* portfolio, i.e. $w_G = w_B$

SEU agents have to clear the supply difference $W_G - W_B \Rightarrow \frac{p_B}{\pi_B} > \frac{p_G}{\pi_G}$

Intuition: to induce SEU agents to clear $W_G - W_B$ p_G will be lower and p_B be higher than in a market populated only by SEU agents sharing the same prior

Market equilibrium: theoretical findings (cont.)

Proposition A:

Suppose $W_G > W_B > W_R \Rightarrow$ **two** *rankings are possible in equilibrium:*

1. $\frac{p_B}{\pi_B} > \frac{p_R}{\pi_R} > \frac{p_G}{\pi_G}$, $y_G > y_R > y_B$ and $w_R < w_G = w_B$
2. $\frac{p_R}{\pi_R} > \frac{p_B}{\pi_B} > \frac{p_G}{\pi_G}$, $y_G > y_B > y_R$ and $w_R < w_G = w_B$

When ranking 1. realizes ($W_G - W_B$ is "large enough") $\Rightarrow$

- the optimal portfolios of the L SEU agents *do not* rank as the total endowment
- the total endowment is the optimal portfolio of the SEU-representative agent rationalizing the market equilibrium

$\Rightarrow$ SEU-representative agent and SEU agents in the market will rank the state-price/state-probability ratio *differently*

CARA utility $u(z) = 1 - e^{-\delta z}/\delta$

· $\delta = a$ risk aversion of the L SEU agents
· $\delta = b =$ risk aversion of the M ambiguity averse agents

The equilibrium prices resulting is the same as if, with the L SEU,

$\rightarrow$ instead of the M ambiguity averse agents we would have

$\rightarrow$ M SEU agents with prior $(\pi_R, q, 1 - \pi_R - q)$:

$$q := \pi_G \frac{\pi_G + \pi_B}{\pi_G + \pi_B e^{\frac{a}{L}(W_G - W_B)}}$$

Dependence of q on $\frac{a}{L}(W_G - W_B)$: channel through which ambiguity aversion impacts asset prices

The M ambiguity averse agents do not hold the imbalance $W_G - W_B$, which is left to the L SEU agents to clear:

$$\frac{a}{L}(W_G - W_B) \uparrow \Rightarrow \; q \downarrow \text{ and } (1 - \pi_R - q) \uparrow \; \Rightarrow \; p_G \downarrow \text{ and } p_B \uparrow$$

Matching theoretical and BGGZ's experimental findings

BGGZ (2010): experimental sessions in which a competitive financial market is embedded in the standard Ellsberg framework.

Their findings:

- individuals are divided between SEU and ambiguity averse

- *experimental evidence that ambiguity aversion matters for equilibrium prices*

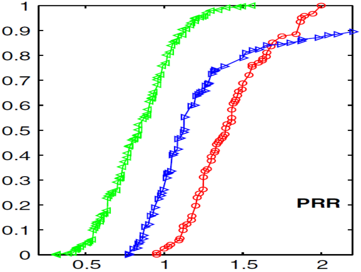
Our theoretical equilibrium prices fully explain and theoretically justify their experimental findings

BGGZ interpret their experimental findings using market with SEU and ambiguity averse α-MEU investors

BGGZ do not derive the equilibrium asset prices, only provide conjectures

Matching theoretical and BGGZ's experimental findings (cont.)

Empirical distribution functions of state-price/state-probability ratios from BGGZ (2010) when $W_G = 272$, $W_B = 162$, and $W_R = 81$.
p_R/π_R; p_B/π_B; p_G/π_G (Figure 8, right panel, in BGGZ (2010))



Two experimental rankings: $\frac{p_B}{\pi_B} > \frac{p_R}{\pi_R} > \frac{p_G}{\pi_G}$ and $\frac{p_R}{\pi_R} > \frac{p_B}{\pi_B} > \frac{p_G}{\pi_G}$

These are exactly the theoretical rankings 1. and 2. in *Proposition A*

Matching theoretical and BGGZ's experimental findings (cont.)

BGGZ (2010) *only expect* ranking 1. $p_B/\pi_B > p_R/\pi_R > p_G/\pi_G$

Proposition A shows that Ranking 2. prevails when $W_B - W_R$ is large enough to imply an SEU optimal portfolios $y_G > y_B > y_R$

Proposition A suggests a possible explanation of why in the experiment prices do not settle in favor of Ranking 1. or Ranking 2.

W_R, W_G, and W_B in the experiment are close to the point at which the change from Ranking 1. or Ranking 2 takes place

Proposition A predicts: *to observe a clean separation of the two rankings, the aggregate wealth W_B should be chosen closer to W_R or W_G, respectively*

Outline

Motivation

Maxmin and α-maxmin expected utility models

Market Model

Standard Ellsberg framework

Extended Ellsberg frameworks

Extended Ellsberg framework ($m \geq 0$, $l \geq 3$)

$m = 1$ risky state, R, with known probability $\pi_R \in (0, 1)$

$l \geq 3$ ambiguous states; $A := S \setminus \{R\}$ set of ambiguous states

Equivalence result does not hold anymore: α-MEU preference do not reduce to maxmin/SEU/maxmax $\Rightarrow$ we study the α-MEU model

To study the α-MEU as function of α *we have to* fix the set of priors of the α-MEU model $\Rightarrow$ we choose

$$\begin{aligned} \mathcal{C}_{\max} &= \{\text{all priors consistent with the uncertainty of the setting}\} \\ &= \{\text{all priors } \pi : \pi(\text{R realizes}) = \pi_R\} \end{aligned}$$

because this choice:

- α is a measure the agent's degree of aversion toward ambiguity
- makes meaningful the comparison between α-$\mathcal{C}_{\max}$-MEU and maxmin preferences by providing a utility specification common to the two classes of models

α-$\mathcal{C}_{\max}$-MEU model

With set of priors $\mathcal{C}_{\max}$, the α-MEU utility reduces to

α-$\mathcal{C}_{\max}$-MEU utility:

$$U(w) = \pi_R u(w_R) + (1 - \pi_R) \left[\alpha \, u(w^A_{\min}) + (1 - \alpha) \, u(w^A_{\max})\right]$$

$w^A_{\min} := \min_{\sigma \in A} w_\sigma$ smallest wealth allocated among the l ambiguous states in the portfolio $w \in \mathbb{R}^{m+l}$

$w^A_{\max} := \max_{\sigma \in A} w_\sigma$ largest wealth allocated among the l ambiguous states in the portfolio $w \in \mathbb{R}^{m+l}$

Remark: α-$\mathcal{C}_{\max}$-MEU is *concave* if and only if $\alpha = 1$

Main findings: Extended Ellsberg framework

▷ Portfolio choice of the $\mathcal{C}_{\text{max}}$-MEU as function of α

- pin down the different attitude (*seeking* and *averse*) towards ambiguity expressed by the $\mathcal{C}_{\text{max}}$-MEU
- disentangle ambiguity seeking from ambiguity averse agents, and among the last ones, α-$\mathcal{C}_{\text{max}}$-MEU from maxmin agents

▷ ambiguity seeking attitudes may prevent the existence of the market equilibrium

α-$\mathcal{C}_{\max}$-MEU portfolios choice

$p \in \mathbb{R}^{1+l}$ state price vector
$p^A_{\min} := \min_{\eta \in A} p_\eta$ lowest price among the ambiguous states prices

Characteristic of the α-$\mathcal{C}_{\max}$-MEU portfolios choice:

→ *only two* types of optimal portfolios, *portfolio inertia at both portfolios*:

1. if $\alpha \geq 1 - \frac{p^A_{\min}}{1-p_R}$ ⇒ optimal portfolio *unambiguous* and *unique*:

$$w = \big(w_R, w, \dots, w, \dots, w\big) \text{ for some } w \in \mathbb{R}$$

2. if $\alpha < 1 - \frac{p^A_{\min}}{1-p_R}$ ⇒ optimal portfolio *ambiguous* and

$$w = \big(w_R, \underline{w}, \dots, \overline{w}, \dots, \underline{w}\big) \text{ for some } \overline{w} > \underline{w}$$

w= *unambiguous* + *bet of* $(\overline{w} - \underline{w})$ *on a cheapest ambiguous states*

ambiguous optimal portfolio might be not unique: number *equals number of ambiguous states with cheapest price*

Exposure to ambiguity of the ambiguous portfolio

▷ *Exposure to ambiguity of the ambiguous portfolio*

$$w = (w_R, \underline{w}, \dots, \overline{w}, \dots, \underline{w}), \text{ is equal to } \overline{w} - \underline{w} > 0$$

$\rightarrow$ the larger α

- the smaller $\overline{w} - \underline{w}$
- the smaller demand for the ambiguous portfolio
  $\alpha = 1 \Rightarrow$ the optimal portfolio is unambiguous

$\rightarrow$ the more u is concave, the smaller $\overline{w} - \underline{w}$

▷ *Allocation between risky and the ambiguous states*:

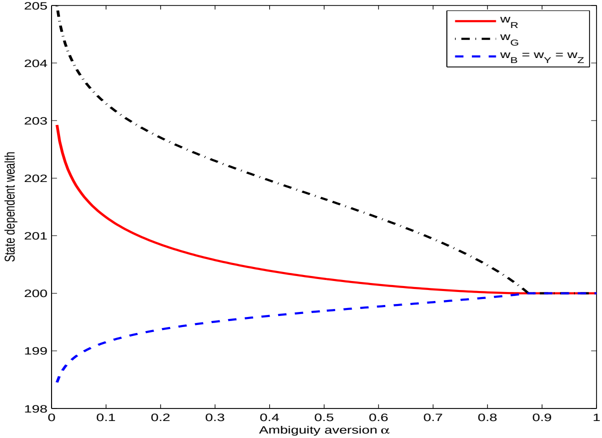
the larger α the smaller $\overline{w} - w_R$

When $\alpha \uparrow \frac{I-1}{I}$, optimal portfolio tends to the unambiguous and optimal allocation is the same of an SEU with prior $\tilde{\pi} = (\pi_R, \frac{1-\pi_R}{I}, \dots, \frac{1-\pi_R}{I})$

Impact of ambiguity aversion α on portfolio choice, $I = 4$

$S = \{R\} \cup A$, $A = \{G, B, Y, Z\}$.

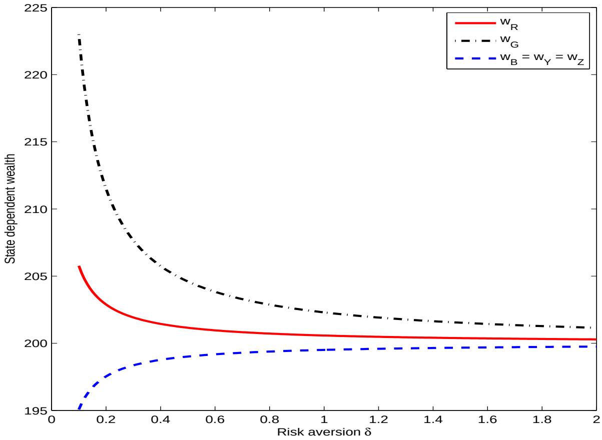
$w = (w_R, w_G, w_B, w_Y, w_Z) = (w_R, \overline{w}, \underline{w}, \underline{w}, \underline{w})$



State dependent wealth impacted by the *degree of ambiguity aversion* α

Impact of risk aversion on portfolio choice, $I = 4$

$S = \{R\} \cup A,\ A = \{G, B, Y, Z\}.$
$w = (w_R, w_G, w_B, w_Y, w_Z) = (w_R, \overline{w}, \underline{w}, \underline{w}, \underline{w})$



State dependent wealth impacted by the *degree of risk aversion δ*, CARA

α-$\mathcal{C}_{\max}$-MEU and maxmin attitude towards ambiguity

$I \geq 3$

- *ambiguity seeking*: α-$\mathcal{C}_{\max}$-MEU agents with $\alpha \in (0, \frac{I-1}{I})$

- **not** *ambiguity seeking*
  - *any* α-$\mathcal{C}_{\max}$-MEU agents with $\alpha \in [\frac{I-1}{I}, 1)$
  - *any* maxmin agent with a set of priors including $\tilde{\pi} :=$ prior assigning equal probability to all ambiguous states

Remark: α-$\mathcal{C}_{\max}$-MEU agent with $\alpha = \frac{I-1}{I}$ is not equivalent – not even observationally – to an ambiguity neutral SEU agent

Lack of equilibrium with ambiguity seeking investors

$S = \{R, G, B, Y\}$, $A = \{G, B, Y\}$ ($m = 1$, $l = 3$)

- SEU agent with prior $\tilde{\pi}$
- maxmin agent with set of priors $\mathcal{C}$, $\tilde{\pi} \in \mathcal{C}$
- α-$\mathcal{C}_{\max}$-MEU agent with $\alpha \in (0, 1)$

Market with 2 agents. Total endowment $W \in \mathbb{R}^{1+3}$, $W_G = W_B = W_Y$

1. *Market agents*: SEU + *ambiguity averse* (e.g α-$\mathcal{C}_{\max}$-MEU $\alpha \in [\frac{l-1}{l}, 1)$ or maxmin) $\Rightarrow$ equilibrium exists:
   - $p \in \mathbb{R}^{1+3}$ with $p_G = p_B = p_Y = \frac{1-p_R}{3}$
   - SEU optimal portfolio $y \in \mathbb{R}^{1+3}$: $y_G = y_B = y_Y$
   - ambiguity averse optimal portfolio $w \in \mathbb{R}^{1+3}$: $w_G = w_B = w_Y$

Lack of equilibrium with ambiguity seeking investors

2. *Market agents*: SEU + ambiguity seeking α-$\mathcal{C}_{\max}$-MEU agent ($\alpha \in (0, \frac{I-1}{I})$) $\Rightarrow$ equilibrium does not exists:

   · ambiguity seeking agent:

   always chooses portfolio exposed to ambiguity with a strictly larger wealth on one cheapest ambiguous states:

   $w \in \mathbb{R}^{1+3}$: $w_\sigma = \overline{w} > \underline{w}$, $w_\eta = \underline{w}$ for any $\eta \in A = \{G, B, Y\} \setminus \{\sigma\}$ where σ cheapest ambiguous state in equilibrium, i.e.

$$p_\sigma \leq p_\eta, \text{ for any } \eta \in A = \{G, B, Y\} \setminus \{\sigma\} \;\; \Rightarrow \tag{5.1}$$

   · SEU agent: to clear the market has to hold a portfolio $y \in \mathbb{R}^{1+3}$:

   $y_\sigma < y_\eta = y_\nu$ for any $\eta \in A = \{G, B, Y\} \setminus \{\sigma\}$

   SEU agent chooses this portfolio only if equilibrium prices satisfy

$$p_\sigma > p_\eta = p_\nu, \text{ for any } \eta \in A = \{G, B, Y\} \setminus \{\sigma\} \tag{5.2}$$

   which is incompatible with (5.1)

Conclusion

α-MEU model increasing popular generalization of the maxmin model

- Standard Ellsberg framework (two ambiguous states):
  - we show that *ambiguity averse α-MEU and maxmin preferences are equivalent*
  - we derive theoretical implications of ambiguity aversion on equilibrium asset prices. These are strikingly consistent with experimental findings in BGGZ (2010) $\Rightarrow$ *ambiguity aversion matters does not wash out in equilibrium*
- Extended Ellsberg framework (at least three ambiguous states):
  - equivalence result does not hold anymore
  - we characterize optimal portfolio of α-$\mathcal{C}_{\text{max}}$-MEU agent. Several differences with the maxmin optimal portfolio (only two types of portfolios, portfolio inertia, demand not unique, ...)
  - pin down ambiguity attitude of α-$\mathcal{C}_{\text{max}}$-MEU agent
  - show that ambiguity seeking behaviour may prevent existence of equilibrium