AMBIGUITY AND PORTFOLIO INERTIA

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In this paper the Portfolio Choice problem is studied under ambiguity, formalized by means of the Choquet Expected Utility. Agents are supposed to be Choquet Expected Utility maximizers and are split into two categories: optimists, who hold a concave capacity, and pessimists, who hold a convex one. Portfolio inertia is defined and analyzed. Necessary and sufficient conditions are established between a specific structure of agents’ beliefs, namely belief commonality, and Portfolio Inertia.

Keywords: Ambiguity; optimism and pessimism; choquet asset pricing rule; portfolio inertia.

1. Introduction

Suppose a security \( a: S \rightarrow \mathbb{R}^S \) is defined by its vector of returns in different states of the world \( S \), such that \( a_j = 1 \) if \( s = j \) and \( a_j = 0 \) otherwise, and let \( q \in \mathbb{R}^S_+ \) be the price vector of securities. It is widely known that any marketable portfolio \( \Psi: S \rightarrow \mathbb{R}^S \) can be constructed and it equals a finite list of marketed securities and, with no transaction costs, the cost of the portfolio \( C(\Psi) \) is \( \sum_{j=1}^{S} a_j q_j \). Such a portfolio can be considered equivalent to an asset \( \beta \) that exactly yields an equal amount. No arbitrage condition implies that two portfolios \( \Psi \) and \( \Theta \), which yield the same payoff, have the same cost, that is, \( C(\Psi) = C(\Theta) \). Under both no arbitrage and no transaction costs conditions, the market value of any asset is the expected value of its discounted future dividends or payments [1]. By no arbitrage and no transaction costs conditions the pricing functional of the economy is unique, positive and linear. The security prices can be normalized so that they sum up to one and the summation of security prices may be interpreted as a probability distribution on the space of states. It is remarkable to note that the derived probability distribution is not a probability distribution (subjective or objective) of the agents on the set of
states of the world, but it is simply a weighting of the states made by prices which express an aggregation of agents behaviors towards uncertainty [4, p. 7].

In some recent articles [4; 14] it has been shown that the valuation of an asset will not be a linear pricing rule (Lebesgue integral of the asset payments) but will be obtained by Choquet integral of the asset payments (non-linear pricing rule), if agents face ambiguity, formalized by means of a capacity on \((S, \Sigma)\). Formally, a capacity is a set-valued function \(v(\cdot)\) defined on \(\Sigma = 2^S\) such that

\[
v(\emptyset) = 0, \quad v(S) = 1, \quad \text{for all} \ A, B \in \Sigma \text{ and } A \subseteq B \Rightarrow v(A) \leq v(B).
\]

A capacity \(v(\cdot)\) is convex if, for all \(A, B \in \Sigma\),

\[
v(A \cup B) \geq v(A) + v(B) - v(A \cap B);
\]

it is concave if the previous inequality is reversed. The Choquet integral is the integral of a monotone function \(f: S \to \mathbb{R}\) with respect to a capacity:

\[
\int_S f(s) dv(s) = \int_0^\infty v(\{s \in S| f(s) \geq t\}) dt + \int_{-\infty}^0 [v(\{s \in S| f(s) \geq t\}) - 1] dt.
\]

Considering a finite state space, the Choquet Integral assumes the following representation:

\[
\int_S f(s) dv(s) = \sum_{k=1}^n f(s_k) \left[ v\left( \bigcup_{j=1}^k (s_j) \right) - v\left( \bigcup_{j=1}^{k-1} (s_j) \right) \right],
\]

where \(v(s_0) = 0\) for simplicity of notation and outcomes are ranked as \(f(s_1) \geq \cdots \geq f(s_n)\). This representation provides a justification for the definition of a Choquet Expected Utility (i.e. an expected utility evaluated by means of a Choquet Integral) maximizer as an optimist or a pessimist. In fact, if the capacity is convex (concave) the term between brackets in the r.h.s. attaches higher (lower) weights to less favorable states with respect to weights that would have received in a standard expected value functional (Lebesgue integral), thus exhibiting pessimism (optimism).a

Uncertainty formalized by means of a capacity might generate portfolio inertia,b that is, an interval of prices within which each agent neither buys nor sells short the asset [5].

Billot et al. [2] consider a general equilibrium model with uncertainty-averse agents (pessimists) and show that the hypothesis of beliefs’ commonality leads to Pareto-efficiency implying that no trade takes place.

We aim at analyzing the relationship between agents’ belief structure and the portfolio inertia connecting the two approaches of [2, 5] in a Portfolio Choice model with ambiguity where agents are split into two classes: the ambiguity-seeking agents

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aWe follow here the approach of Ghirardato and Marinacci [7] where it is shown that convexity (concavity) is a sufficient condition for a capacity to express ambiguity aversion (seeking). For the same reason we use the terms ambiguity aversion (seeking) and pessimism (optimism) as synonymous. For a different approach see [6].

bSee Sec. 2 for a formalization of portfolio inertia.
(or optimists) and the ambiguity-averse ones (or pessimists). More precisely, we assume that a finite set \( S \) of states of the world exists; agents face ambiguity about future events towards which they have a specific attitude, namely favor or aversion, but they have common beliefs. Rather than supposing that agents foresee a common expectation (as in [12] for instance), we suppose that the commonality of beliefs hypothesis implies that agents share some common doubt on the probability distribution. That is to say, agents agree about the structure of the portfolio that generates a given asset, but they disagree with respect to probability of future states of the world. In other words, they assume that an asset is completely defined by its flows of payments and take as given the structure of the replicating portfolio of securities. However, since the probability distribution induced by the replicating portfolio does not represent the probability distribution on future events, they might have quite different probability distributions, that depend on their beliefs about these events. These beliefs are common since they have at least one common price on which they agree.

We show that Portfolio inertia arises under (and only under) the hypothesis of belief commonality. This has quite a strong consequence. As a matter of fact, belief commonality requires that for some price, agents’ beliefs coincide. Our study shows that such a condition is necessary and sufficient to prevent agents to trade for all levels of prices, provided that agents are pessimists (ambiguity-seekers) or optimists (ambiguity-averse).

The paper is organized as follows. In Sec. 2 the model is worked out. Portfolio inertia is formalized, the relationship between inertia and optimism and pessimism is stated and proved. A simple numerical example of inertia and trading is in Sec. 3. Section 4 contains some concluding remarks.

2. Ambiguity and Portfolio Inertia

Let \( S = \{s_1, \ldots, s_n\} \) be a non empty set of states of the world and let \( \Sigma = 2^S \) be the set of all events. On the measurable space \((S, \Sigma)\) let \( \pi \) be a probability, or measure, that is, a function \( \pi: \Sigma \rightarrow [0, 1] \); then the triple \((S, \Sigma, \pi)\) is a probability space.

It is assumed that an asset is fully defined by its future payments, which depend on the state of the world that will occur. By no arbitrage condition, there exists a unique additive measure \( \pi \), such that the value of any asset in \( L \), the set of all marketed and marketable assets,\(^c\) is the expectation of its payments. As a consequence, an asset may be considered a random variable \( \beta: S \rightarrow \mathbb{R} \) of its payments \( \beta(s_i) \), where \( s_i \in S \), and assets are ranked with respect to their market values, that is \( \forall \beta, \gamma \in L, \beta \geq \gamma \) if and only if\(^d\) \( \int_S \beta d\pi \geq \int_S \gamma d\pi \).

\(^c\)The set of all assets \( L \) can be the normed space \( L^2(S, \Sigma, p) \) endowed with the norm topology. For instance, see [4].

\(^d\)The \( \geq \) is in the usual way and the induced ranking of assets is monotonic and respects monotonic uniform convergence [4].
The replicating portfolio defines the value of a given asset; it is assumed to be Radner’s common expectation. Nevertheless, agents face ambiguity and they are assumed to be either pessimists or optimists.\footnote{Usual conditions on preferences are assumed that allow to represent agents’ attitude towards risk by means of a utility function, as distinguished from agents’ attitude towards uncertainty that is captured by the concavity or convexity of a capacity.}

Let \( v: \Sigma \to [0,1] \) be a capacity and \( \int_S \beta \, dv \) the Choquet Integral (CI) defined w.r.t. \( v \). Assume there is a representative ambiguity-averse player (pessimist, henceforth) who holds a belief given by the convex capacity \( v_p \), and for whom \( \int_S \beta \, dv_p \) is her Choquet integral. Similarly, let \( v_0 \) be the concave capacity which represents the representative ambiguity seeker (optimist, henceforth) player’s belief and let \( \int_S \beta \, dv_0 \) be her Choquet integral. We consider capacities that have non-empty cores, where the core is the set of additive probabilities that either majorize or minorize the non-additive convex or concave measure, respectively:

\[
\text{core}(v_p) = \{ \pi | \pi(A) \geq v_p(A), \ \forall \ A \in 2^S \}, \\
\text{core}(v_0) = \{ \pi | \pi(A) \leq v_0(A), \ \forall \ A \in 2^S \}. \footnote{Notice that to express pessimism or optimism we only consider capacities with non empty cores, such as in [7].}
\]

Suppose an agent will sell short the asset \( \beta \) if and only if its price is higher than its maximum expected value in the core, i.e

\[
p > \max_{\pi \in \text{core}(v_{i=0,p})} \left\{ \int_S \beta \, d\pi \right\};
\]

define by

\[
P^- = \left\{ p \in P | p > \max_{\pi \in \text{core}(v_{i=0,p})} \left\{ \int_S \beta \, d\pi \right\} \right\}
\]

the set of price for which an agent will sell the asset, with \( p^- = P^- \) a generic element. Similarly, an agent will buy the asset if and only if its price is lower than its minimum expected value:

\[
p < \min_{\pi \in \text{core}(v_{i=0,p})} \left\{ \int_S \beta \, d\pi \right\}.
\]

Denote by

\[
P^+ = \left\{ p \in P | p < \min_{\pi \in \text{core}(v_{i=0,p})} \left\{ \int_S \beta \, d\pi \right\} \right\}
\]

the set of prices for which an agent will buy the asset, \( P^+ = \{ \ldots, p^+, \ldots \} \).

Note that for an additive probability the core is a singleton and thus the maximum expectation will coincide with the minimum one:

\[
\max_{\pi \in \text{core}(v_{i=0,p})} \left\{ \int_S \beta \, d\pi \right\} = \min_{\pi \in \text{core}(v_{i=0,p})} \left\{ \int_S \beta \, d\pi \right\}.
\]
On the contrary, under ambiguity portfolio inertia can be defined by identifying a whole set of expected values for which the agent neither buys nor sells the asset, since

\[
\max_{\pi \in \text{core}(v_{1i=0,p})} \left\{ \int_S \beta d\pi \right\} \neq \min_{\pi \in \text{core}(v_{1i=0,p})} \left\{ \int_S \beta d\pi \right\}.
\]

Formally, portfolio inertia correspond to the case in which \(\max\{P^+\} < \min\{P^-\}\).

Notice that in order to analyze the relationship between the inertia and agents’ beliefs we need to specify agents’ behavior for all possible acts in the market, namely buying, selling or neither buying nor selling the asset. The optimist evaluates her certainty equivalent by means of the best additive distribution in the core of her capacity. We suppose that she sells the asset if and only if its price is higher than the maximum possible expected value of the replicating portfolio, which is evaluated by means of the maximum additive distribution in the core of her concave capacity. For the dual problem, namely buying, we consider the dual capacity. Thus, we suppose that she buys the asset if and only if its price is lower than the minimum possible expected value calculated with respect to the dual capacity.

Consider now the pessimist. He will consider the worst case, i.e. the expected value associated with the worst distribution in the core of his (convex) capacity. Thus, we suppose he buys the asset if and only if its price is lower than such a certainty equivalent. On the contrary, he sells the asset (dual problem) if and only if its price is higher than the expected return associated with the maximum distribution in the core of his dual capacity. Finally, agents share common beliefs on \(\beta\) if there is at least one price in common for which both classes of agents face inertia, i.e., the intersection of the cores is non-empty (it might be a singleton or it may encompass more than a single price).

We want to investigate if the hypothesis of belief commonality is a necessary and/or sufficient condition for optimists and pessimists to induce them not to trade among each other, thus generating portfolio inertia. In other words, we ask ourselves whether sharing some common doubts is sufficient to restrain players from trading for all prices, i.e. even for those prices for which they feel sufficiently “sure” to buy or sell the asset. We can show that this is the case, i.e., there will be portfolio inertia if and only if agents have common beliefs:

**Proposition (Portfolio Inertia).** In financial markets with optimists and pessimists there will be portfolio inertia if and only if agents share at least a common belief on the asset \(\beta\).

**Proof.** Let us prove the if condition. Suppose \((a)\): the pessimist buys and the optimist sells. This means that

\[
p < \min_{\pi \in \text{core}(v_p)} \left\{ \int_S \beta d\pi \right\}
\quad \text{for the pessimist},
\]

\[
p > \max_{\pi \in \text{core}(v_0)} \left\{ \int_S \beta d\pi \right\}
\quad \text{for the optimist}.
\]
For every convex capacity on \((S, \Sigma)\) and every function \(\beta: S \rightarrow \mathbb{R}\) there exists a set \(\Pi = \{\ldots, \pi, \ldots\}\) of additive probabilities on \((S, \Sigma)\), such that, for all events,

\[
\pi(\cdot) \geq v_p(\cdot) \quad \text{and} \quad \int_S \beta dv_p = \min \left\{ \int_S \beta d\pi | \pi \in \Pi \right\}
\]

(in short, \(\beta\) is a threshold value that can be considered as the highest price at which the pessimistic agent will wish to buy a given asset). Similarly, for every concave capacity on \((S, \Sigma)\) and every function \(\beta: S \rightarrow \mathbb{R}\), there exists a set \(\Pi^\circ\) of additive probabilities on \((S, \Sigma)\) such that for all events [3, Theorems 3 and 3’]

\[
\pi(\cdot) \leq v_0(\cdot) \quad \text{and} \quad \int_S \beta dv_0 = \max \left\{ \int_S \beta d\pi | \pi \in \Pi^\circ \right\}
\]

(in short, \(\beta\) is a threshold value that can be considered as the lowest price at which the optimistic agent will wish to sell a given asset). If the optimist and the pessimist share common beliefs, \(\Pi \cap \{\Pi^\circ\} \neq \{\emptyset\}\); thus,

\[
p^+ = p < \int_S \beta dv_p = \min \left\{ \int_S \beta d\pi | \pi \in \Pi \right\} \leq \max \left\{ \int_S \beta d\pi | \pi \in \Pi^\circ \right\}
\]

\[
= \int_S \beta dv_0 < p = p^- ,
\]

which implies inertia.

Consider \((b)\): the optimist is buying, the pessimist is selling. This means

\[
p > \max_{\pi \in \text{core}(v_p)} \left\{ \int_S \beta d\pi \right\} \quad \text{for the pessimist ,}
\]

\[
p < \min_{\pi \in \text{core}(v_0)} \left\{ \int_S \beta d\pi \right\} \quad \text{for the optimist .}
\]

Recall that the CI is \(\int_S \beta dv_p\) for the pessimist and it is \(\int_S \beta dv_0\) for the optimist. For every capacity \(v\), there exists a dual capacity defined as \(v^d = 1 - v(A^c) \forall A \subseteq \Sigma\), that shows to which extent the agent believes the complement of an event can happen (for all events). See that the dual of \(v_p\), (denoted by \(v^d_p\)) is concave, and the dual of \(v_0\) (denoted by \(v^d_0\)) is convex. Suppose that agents share common beliefs. By applying the same argument of the previous case to \(\int_S \beta dv^d_p\) and \(\int_S \beta dv^d_0\) we would then have

\[
p^- = p > \int_S \beta dv^d_p = \max \left\{ \int_S \beta d\pi | \pi \in \Pi^\circ \right\} \geq \min \left\{ \int_S \beta d\pi | \pi \in \Pi \right\}
\]

\[
= \int_S \beta dv^d_0 > p = p^+ ;
\]

as a consequence, inertia occurs.

Let us prove now the only if part. Suppose that agents do not share common beliefs:

\[
\left\{ \int_S \beta d\pi | \pi \in \Phi \right\} \cap \left\{ \int_S \beta d\pi | \pi \in \Phi^\circ \right\} = \{\emptyset\} ,
\]
where \( \{ \Phi \} \) and \( \{ \Phi^o \} \) are the core of the convex capacity \( \nu_d \) and the concave capacity \( \nu_0 \) that express the pessimist’s and the optimist’s beliefs, respectively. Then, either (c) \( \min \{ \Phi \} > \max \{ \Phi^o \} \) or (d) \( \min \{ \Phi^o \} > \max \{ \Phi \} \) holds true.

If (c) occurs, by simply choosing a price \( p \) such that \( \max \{ \Phi^o \} < p < \min \{ \Phi \} \) we have that

\[
 p < \int_S \beta dv_p = \min \left\{ \int_S \beta d\pi \mid \pi \in \Phi \right\},
 p > \int_S \beta dv_0 = \max \left\{ \int_S \beta d\pi \mid \pi \in \Phi^o \right\},
\]

where \( \Phi = \Pi, \Phi^o = \Pi^o \); this implies \( \min \{ P^+ \} > \max \{ P^- \} \), i.e. trade takes place. This is the case in which the pessimist buys, the optimist sells.

If (d) happens, choose a price \( p \) such that \( \max \{ \Phi \} < p < \min \{ \Phi^o \} \). It follows that

\[
 p > \int_S \beta dv_p^d = \max \left\{ \int_S \beta d\pi \mid \pi \in \Phi \right\},
 p < \int_S \beta dv_0^d = \min \left\{ \int_S \beta d\pi \mid \pi \in \Phi^o \right\},
\]

where \( \Phi = \Pi^o, \Phi^o = \Pi^o \). Again, \( \min \{ P^+ \} > \max \{ P^- \} \), i.e. there is trade, with the pessimist selling and the optimist buying.

\( \square \)

### 3. Examples

Let us illustrate the Proposition with two simple numerical examples in which we show when inertia and trading occur.

Consider three states of the world, \( S = \{ s_1, s_2, s_3 \} \) and the asset returns \( q_i = 2, 1, -1 \), where \( i = s_1, s_2, s_3 \). Assume that there is a pessimistic agent who holds the following capacity

\[
v_p(s_i) = 1/6, \quad v_p(s_i \cup s_j) = 3/4, \quad i, j = \{1, 2, 3\}, \quad \text{for } i \neq j.
\]

His Choquet expected value is:

\[
v_p(s_1) q(s_1) + [v_p(s_1 \cup s_2) - v_p(s_1)] q(s_2) + [1 - v_p(s_1 \cup s_2)] q(s_3) = 2/3.
\]

This is the minimum value of his inertia interval, i.e., \( \min_{\pi \in \text{core}(v_p)} \{ \int_S \beta d\pi \} \). Defining the dual capacity of \( v_p \), that is \( v_p^d = 1 - v_p(A^c) \forall A \subseteq \Sigma \), and calculating his Choquet expected value with respect to \( v_p^d \) we obtain:

\[
v_p^d(s_1) q(s_1) + [v_p^d(s_1 \cup s_2) v_p^d(s_1)] q(s_2) + [1 - v_p^d(s_1 \cup s_2)] q(s_3) = 11/12.
\]

This is the inf of the selling prices (i.e. the upper level of the inertia interval or \( \max_{\pi \in \text{core}(v_p)} \{ \int_S \beta d\pi \} \)). Consider the optimistic agent who holds the following beliefs:

\[
v_0(s_i) = 5/12, \quad v_0(s_i \cup s_j) = 15/24, \quad i, j = \{1, 2, 3\}, \quad \text{for } i \neq j.
\]

Her Choquet expected value is:

\[
v_0(s_1) q(s_1) + [v_0(s_1 \cup s_2) - v_0(s_1)] q(s_2) + [1 - v_0(s_1 \cup s_2)] q(s_3) = 2/3.
\]
This is the upper level of her inertia interval, \( \max_{\pi \in \text{core}(v_0)} \{ \int_S \beta d\pi \} \). Defining the dual capacity of \( v_0 \), which is \( v_0^d = 1 - v_0(A^c) \ \forall A \subseteq \Sigma \), and evaluating her Choquet expected value with respect to \( v_0^d \) we obtain

\[
v_0^d(s_1)q(s_1) + [v_0^d(s_1 \cup s_2) - v_0^d(s_1)]q(s_2) + [1 - v_0^d(s_1 \cup s_2)]q(s_3) = \frac{13}{24},
\]

that is, the lower level of her inertia interval or \( \max_{\pi \in \text{core}(v_0)} \{ \int_S \beta d\pi \} \). As a result, the inertia interval is \([13/24, 2/3]\) for the optimist, \([2/3, 11/12]\) for the pessimist and no trade occurs.

Suppose, on the contrary, that the pessimistic agent holds the capacity

\[
v_p(s_i) = 1/5, \ v_p(s_i \cup s_j) = 31/40, \ i, j = \{1, 2, 3\}, \text{ for } i \neq j.
\]
His Choquet expected value is:
\[ v_p(s_1)q(s_1) + [v_p(s_1 \cup s_2) - v_p(s_1)]q(s_2) + [1 - v_p(s_1 \cup s_2)]q(s_3) = 3/4 \]
and it is the upper limit of his buying prices. The Choquet expected value of the asset evaluated with respect to the dual capacity, on the other hand, yields
\[ v_p^d(s_1)q(s_1) + [v_p^d(s_1 \cup s_2) - v_p^d(s_1)]q(s_2) + [1 - v_p^d(s_1 \cup s_2)]q(s_3) = 33/40 \]
which is the lower limit of his selling prices. Let the optimist hold the capacity
\[ v_0(s_i) = 2/3, \quad v_0(s_i \cup s_j) = 11/24, \quad i, j = \{1, 2, 3\}, \quad \text{for } i \neq j. \]
Her Choquet expected value of the asset is
\[ v_0(s_1)q(s_1) + [v_0(s_1 \cup s_2) - v_0(s_1)]q(s_2) + [1 - v_0(s_1 \cup s_2)]q(s_3) = 7/12. \]
The latter is the lower limit of her selling prices, while
\[ v_0^d(s_1)q(s_1) + [v_0^d(s_1 \cup s_2) - v_0^d(s_1)]q(s_2) + [1 - v_0^d(s_1 \cup s_2)]q(s_3) = 5/24 \]
is the upper limit of her buying prices (where \( v_0^d \) is the dual of \( v_0 \)). As a consequence, there is no intersection between the inertia intervals, respectively \([3/4, 33/40]\) for the pessimist and \([5/24, 7/12]\) for the optimist, and there exists the set \([7/12, 3/4]\) of expected values, for which the pessimist buys and the optimist sells.

In Fig. 1, we give a representation of our Proposition for the case of (a) inertia, (b) trade where the pessimist is buying, the optimist is selling and (c) trade where the pessimist is selling, the optimist is buying (+ denotes \( P^+ \), − denotes \( P^- \) and the interval \([\cdots]\) denotes portfolio inertia). Cases (a) and (b) provide an illustration of our numerical examples.

4. Concluding Remarks
The analysis we have developed here can be encompassed within that flow of literature that studies the relationship between agents' structure of belief and arbitrage opportunities \([8, 15]\) starting from the well-known no-trade theorem of Milgrom and Stokey \([11]\). In particular, we have considered necessary and sufficient conditions under which there is no trade when agents are allowed to hold non additive beliefs about the returns of an asset. A similar independent approach has been followed by Ma \([9]\), who studied what are the minimum requirements on preferences under which the no trade result holds.\(^8\) Our work differs from the latter analysis in that we set a one-period setup that allows to dispose of any problem of beliefs’ updating consistency and to focus on the relationship between preferences (based on beliefs\(^b\)) and inertia, while Ma \([9]\) pointed out a dynamic framework where no trade occurs \(8\)We wish to thank an anonymous referee for pointing out this latter paper.
\(b\)In our behavioral assumption we implicitly set preferences based on non-additive beliefs since agents are supposed to buy (sell) the asset if the price is lower (higher) than the minimum (maximum) expected value.
even if agents do not have preferences based on beliefs (as in [10]), provided that
the preference system is dynamic consistent.¹

Billot et al. [2] have proved a no trade theorem for pessimistic agents who share
common beliefs in a general equilibrium setting. A link might be established between
our proposition and their no trade result, which is based on a separating theorem for
convex sets, since in our work both optimists and pessimists express their beliefs by
capacities that have non empty convex cores: Π⁺ and Π (respectively). However, we
believe that our Portfolio Choice approach sheds new interesting light on the finan-
cial market analysis in all those cases in which agents are not behaving as “perfect”
expected utility maximizers. In particular, it has the following advantages:

(i) it relies on simple behavioral hypotheses of portfolio selection,
(ii) it contains an intuitive description of inertia intervals and
(iii) it allows to highlight consequences that are derived by dropping the hypothesis
of beliefs’ commonality since two quite different outcomes can be sustained, in
which the optimistic agents are selling and the pessimistic ones are buying or
vice versa, according to their respective attitude towards uncertainty.

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¹And Piece-wise Monotonic. See [9, Sec. 4].
²Consider, for instance that growing stream of literature which goes under the name of behavioral finance, that highlights the discrepancies between theoretical previsions and effective market behavior. For a review, see [13].


