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Capability satisficing in high frequency trading

Ben Van Vliet

Center for Strategic Finance, Stuart School of Business, Illinois Institute of Technology, 565 W. Adams, Chicago, IL 60661, United States

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ABSTRACT

This paper explains the capability theory of how HFT firms make allocation decisions under uncertainty, and shows how capability maximization is precisely consistent with utility theory. The issue, however, is how these firms actually make allocation decisions in practice. Using the Gioia methodology, this paper presents evidence from interviews with HFT professionals and specialist media that suggest that these firms are capability satisficers. Capability theory is also consistent with bounded rationality and the adaptive markets hypothesis, and defines the point at which these firms reach a satisfactory solution. Thus, capability reconciles mainstream theory and the more realistic, behavioral theories based on observation of industry practice. The methodology developed can be applied to any firm that makes algorithmic decisions under uncertainty.

1. Introduction

> Finance is the application of economic principles to decision-making that involves the allocation of money under conditions of uncertainty. Investors allocate their funds among financial assets in order to accomplish their objectives.
> Fabozzi and Drake (2009)

Mean-variance expected utility has been the foundation of decision theory in mainstream finance for decades. But, the advent of automated trading has changed everything and new theories are needed (see O'Hara, 2015). Today, the markets are ecologies of algorithms (Hasanhodzic et al., 2011; Farmer and Skouras, 2013; MacKenzie, 2014). These algorithms encapsulate trading strategies that, presumably, have some efficacy. Among these, high frequency strategies alone account for over 70% of the daily trading volume (Brogaard, 2010; Hoffmann, 2014).

The mainstream theories have a difficult time with high frequency trading (HFT). The profits some of these strategies earn and the consistency with which they earn them are inconsistent with the efficient markets hypothesis. This leads some to conclude either that those theories are wrong or that HFT firms (henceforth firms) are doing something nefarious. Behavioral theories in finance also have a difficult time with HFT. The systems these firms create do what Richard Thaler says people cannot do—"calculate like a computer and have no self-control problems[1] (see Orrell, 2010)." While this may be true, Kumiega and Van Vliet (2012) argue that behavioral biases in the management of algorithmic strategy research and development projects and on/off allocation decisions open the door to (potential) irrationality.

Whatever the case, this paper overcomes these difficulties by starting from first principles and arguing these firms are something new. They are neither pure, market-risk-averse utility maximizers (as in mainstream finance theory) nor pure, risk-neutral profit maximizers (as in theory of the firm). They are a combination of both, because they are sensitive to both

E-mail address: bvanvliet@stuart.iit.edu

[1] That is, assuming the strategy is running in control or to specification. See Kumiega and Van Vliet (2012).

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market risk and demand risk. They are in theory something called capability maximizers (from the perspective of mainstream finance and a rational, idealized world) or they are capability satisficers (from the perspective of behavioral finance and a real, boundedly rational world) in the sense of Simon (1965) (henceforth Simon). Thus, the concept of capability allows us to "move back and forth from the world of theory to the world of action (Ostrom, 1990)," by reconciling the mainstream-finance/behavioral-finance dichotomy. It does so by assuming the evolutionary, or biological, approach to markets (see Farmer and Lo, 1999; Farmer, 2002; Farmer and Skouras, 2013) under the adaptive markets hypothesis (AMH) of Lo (2004, 2005), where "financial agents compete and adapt, but not. . .in an optimal fashion (Lo, 2008)."

Empirically, while HFT firms are notoriously secretive, I was able to follow the methodology of Gioia et al. (2013) and interview seven HFT industry professionals. These interviews shed light on emerging issues on how these firms compete and adapt. The aim is to contribute to the theoretical and case study literatures on HFT by taking a cross-disciplinary view. While the sample is small, common concepts and themes across firms appear to support the aggregate dimension that (rather than optimizing) these firms are capability satisficers. They allocate to strategies that achieve some target, goal, or aspiration level, or simply that are "good enough." Quotes drawn from the specialist media corroborate these interviewees' comments.

Relative to the existing literature, this paper makes four contributions. One, this paper presents capability as a descriptive theory of decision-making in HFT under the AMH. Two, this paper extends an existing profit function for HFTs and represents capability using the more intuitive statistics of the distribution of the sample sum, rather than the sample mean. Third, this paper extends capability theory by explaining these firms' time *and* risk preferences according to a ratio of measurable components—the Cooper ratio—that shows that capability is precisely consistent with utility maximization. Four, as maximization is not possible in practice, this paper presents qualitative evidence that these firms exhibit satisficing behavior when making on/off allocation decisions.

The remainder of this paper proceeds as follows. Section 2 provides some background concepts, including a review of the relevant literature, the economic premise of capability theory, and an update to the HFT profit model. Section 3 presents a numerical implementation of an example HFT strategy. Section 4 redefines capability using the distribution of the sample sum. Section 5 connects capability to utility maximization. Section 6 presents the evidence for the proposition that these firms are in practice capability satisficers. Section 7 concludes.

2. Background and literature review

In mainstream finance theory, Von Neumann and Morgenstern's (1947) expected utility theorem describes people's preferences with regard to decision making under uncertainty under the assumption of rationality. Further, it accounts for risk aversion, meaning people's utility functions are concave. This leads to expected utility maximization and the measure of relative risk aversion λ of Arrow (1965) and Pratt (1964). The first order condition of optimality of expected utility leads to the well-known Sharpe ratio (*SR*) (Sharpe, 1966), which is commonly used to rank the performance of portfolio strategies, where $SR = (E(r) - r_f)/\sigma$. For *any* investor, the higher the *SR*, the higher the expected utility, regardless of their objectives or their idiosyncratic level of risk aversion λ.

Kumiega et al. (2014) suggest that the performance of HFT strategies is more appropriately assessed against a capability ratio C_{pl} as in Eq. (1), which measures of the ability of a process to satisfy a lower specification limit (Kane, 1986). In (1) μ_n is the average expected return per trade, σ_n is the standard deviation of expected returns per trade, and c is the specification limit, which is the average fixed cost necessary to build and operate these infrastructure-intensive strategies.[2]

$$C_{pl}(n) = \frac{\mu_n - c}{3\sigma_n} \geq 1 \tag{1}$$

Cooper et al. (2015) adds that non-normality in the returns of strategies can be more precisely modeled and that capability can be a proxy for prudence in algorithmic trading.

These authors present capability as a prescriptive framework, combining statistical control and risk-adjusted performance measurement. Firms *ought* to invest in algorithmic strategies with capability ratios that are greater than one. Their assumption is that stationary *trading profits* are available to firms that invest in the correct combination of technologies and algorithms. Consistent profitability is a stylized fact of HFT (see for example, Hadfield, 2017; Baron et al., 2012; Kirilenko et al., 2015), and it is what justifies these firm's large, up-front investments in research and technological infrastructure.

In behavioral economics, Simon's contributions on bounded rationality and satisficing form the foundation of theories derived from observation of agents (Schwartz, 2002). A wide body of literature develops these concepts, including some contributions related to the market ecology of algorithms. Brennan and Lo (2012) develop a binary choice model of decisions and show that "bounds on rationality are determined by physiological and environmental constraints." Hasanhodzic et al. (2011) "suggest that a reinterpretation of market efficiency in computational terms might be the key to reconciling [the efficient markets hypothesis] with the possibility of making profits based on past prices alone. . .It does not make sense to talk about market efficiency without taking into account that market participants have bounded resources."

In addition to the literature on the AMH already discussed, other authors in finance have also addressed satisficing, the "decision-making procedure or cognitive heuristic that entails searching through the available options just long enough

[2] Expected utility theory conveniently assumes away these costs, largely because for longer-term investors they are relatively small.