Allocation of Effort to Risky Decisions

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Abstract

This research investigates expertise at decision making under risk and the allocation of cognitive effort as risky decisions are made[1]. We conceptualize risk within a space defined by decision variables that managers monitor in their environment. We present a representation of the risk space that captures how foreign exchange traders understand risk in spot currency markets. Results from an experiment with professional traders as subjects show that the risk space explains whether and when traders make decisions to buy, sell, and hold spot positions in foreign currencies. An index of cognitive effort is presented that can be used to predict subjects' level of confidence in their assessments of market behavior. Effort is relatively high when conditions are likely to trigger uncertainty. Effort is relatively low when markets act as expected.

Introduction

We propose that the decision making behavior of managers can be explained in terms of a risk space defined by the decision variables they monitor in their environment. Events are traced and evaluated within the risk space relative to thresholds for acceptable risk (Senders, 1966; Moray, 1986). The thresholds for risk parse the risk space into decision regions. Each region is associated with a specific variety of risk. A representation of the risk space, the phase plane (Phatak & Bekey, 1969), is presented. We propose that the time-trace of decision variables through the phase plane explains the actions managers take to manage risk.

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The domain of study is foreign exchange (currency) trading. Subjects in our experiment are professional traders employed by a large regional bank to buy and sell foreign currencies for the purpose of generating profits. They routinely manage the risks associated with exposure to the volatile international currency markets.

Foreign exchange markets are an amalgam of the composite activity of traders around the world. As forums for action by a large group of goal-seeking agents, foreign exchange markets act with a quixotic intentionality that traders continually attempt to assess to infer its future behavior. The assessments or expectations largely drive traders' "pro-active" decision making behavior.

We propose that assessing market intentionality requires and receives deliberate, effortful thought. We hypothesize that associating a continuous measure of cognitive effort with overt decision behavior should reveal that effort is high when the intentionality of the market is hard to fathom and is low when the market behaves in accord with expectations.

In this paper we present one episode from an experimental session to illustrate how the phase plane representation of the trader's risk space explains whether and when subjects implement decisions to manage the risks associated with foreign exchange trading. The scenario also illustrates that cognitive effort varies with and can be used to predict the level of fit between expectations and actual market behavior.

Risk in Foreign Exchange Trading

Traders take "positions" in foreign currencies by buying and selling dollars in exchange for a foreign currency. A position may be "long" dollars or "short" dollars. A trader takes a long dollar position by buying dollars and selling an equivalent amount of foreign currency. Long dollar positions profit when the dollar appreciates against (buys more of) the

foreign currency. Taking a short dollar position involves selling dollars and buying a foreign currency. Short dollar positions profit when the value of the dollar declines.

Because foreign currencies are negotiable only in specialized international markets, holding a foreign currency entails assuming the risk of losing equity while owning a non-negotiable asset. For traders, the level of risk is determined solely by the magnitude of the potential loss (Zaheer, 1991). In contrast to the conceptualization of risk presented by behavioral decision theory (e.g., Fischhoff, Slovic, Lichtenstein, Read, & Combs, 1978), probability does not figure into traders' thinking about risk (Zaheer, 1991). Risk increases with the size of a position.

The sources of risk in foreign exchange are (1) changes in the price at which currencies can be bought and sold, (2) the rate at which a price changes, and (3) uncertainty about future market behavior. The actual value of a price has little consequence; it is the change in price that determines profit or loss, and hence, risk.

The direction of price movement is calculated relative to a reference point called the "all-in rate". The all-in rate is the price at which a trader would break even on the position she has taken. This reference point is dynamic. It changes as she makes trades. For instance, taking a profit on a portion of a long position reduces the price at which she would break even on the remaining position. Thus, the reference point against which risk is judged is a function not only of the environment (the market) but also of her trading activity. A trader can manipulate this dimension of risk by taking action in her environment.

The effect of a dynamic reference point is dramatic. Taking a profit makes it easier to continue to take profits. Conversely, taking a loss makes it more difficult to turn a profit.

The second dimension of risk in currency trading is the time rate at which prices change. Currency markets are volatile and have a knack for turning suddenly against a position. Market movements can rapidly outstrip traders' ability to attend and respond. The trader who fails to read a significant headline or who gets caught in a contrary market stands to lose a large sum of money in a very few minutes. This dimension of risk is purely environmental and independent of a trader's actions.

The third dimension of risk is the trader's uncertainty of the markets. We conceptualize a two-step process to assess this uncertainty. The first step is the attribution of intentionality to the market. For example, we can imagine a trader's mental soliloquy (Dennett, 1983): "Strikes are crippling the German economy. I think the market believes the dollar will rise against the mark". The second step in this process is an evaluation of confidence in this attribution of intentionality: "I'm sure that's what they'll do". Confidence about future market behavior reduces the risk of taking a long dollar position against the mark.

There are three varieties of risk in currency markets: (1) paper losses, (2) diminishing gains, and (3) neglected profits. For long positions, the risk of a paper loss appears whenever the price at which a currency can be exchanged falls below the all-in rate. The risk of diminishing gains is opportunity lost that appears whenever the sign (+ or -) of the time rate of price change devalues the position. The risk of neglected profit appears whenever profits are so large that the trader cannot afford not to take them: "You never go broke taking profits".

Different cues signal the three varieties of risk. For long positions, prices below the all-in rate signal the risk of paper losses. Falling prices signal the risk of diminishing gains. Prices well above the all-in rate signal the risk of neglected profit. Traders attend to four quantitative decision variables to assess these risks: the all-in rate, position size, the direction of and the rate of price movements.

Risk Space

We conceptualize the direction and rate of price change as defining a risk space that explains whether and when traders allocate effort. Figure 1 introduces an observer construct called the "phase plane". This representation of risk space was originally designed to serve as a graphic aid to assist agents performing the task of monitoring time-varying phenomena (Phatak & Bekey, 1969; Moray, 1986). The axes of the phase plane are simple qualitative functions of the four quantitative decision variables that traders monitor.

The horizontal axis of the phase plane is defined by the difference between the current price, p_n, and

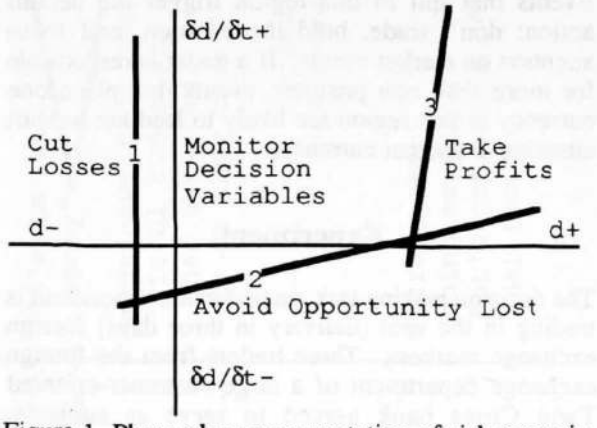


Figure 1 Phase plane representation of risk space in foreign exchange trading

the trader's all-in rate, p_a, and is scaled by the size of her position, S: $d = (p_n - p_a)*S$. As shown in Figure 1, positions profit with positive values of d. This axis quantifies the profit (loss) that would be made by squaring (closing) the position at the current market price. On the job, traders keep track of this dimension of risk with qualitative "ball park" estimates that they make precise when time permits.

The vertical axis of the phase plane is defined by a qualitative calculus that assesses the time rate of price change: $\delta d/\delta t = (p_n - p_{n-1})/(t_n - t_{n-1})$. This axis accounts for the second dimension of risk in the markets: its volatility and seemingly contrary intent. The vertical axis is scaled by heuristics about how fast a price is likely to turn. It captures the risk associated with market behavior that can readily outstrip the trader's ability to attend and respond.

Thresholds for acceptable risk parse the risk space into homogeneous regions associated with specific varieties of risk. Three constraints on a trader's behavior guide the location of these thresholds. Constraint 1 is "cut losses". Taking large losses is bad business. The threshold for cutting losses parallels the vertical axis at some small value of paper losses. Market events that drive a position to the left of this threshold signal the risk of paper losses. Constraint 2 is "avoid opportunity lost". Traders trim profitable long positions when they consistently lose value at an unacceptable rate, $\delta d/\delta t$-. The threshold for opportunity lost is sub-parallel to the horizontal axis. Market events that drive a position below this threshold signal the risk of diminishing gains. Constraint 3, "take the money and run", is a variation on avoiding opportunity lost. Traders generally lock-in a proportion of their paper profits when d+ reaches heady proportions. The threshold for reaping a large gain is sub-parallel to the vertical axis at some large value of paper gain. Market events to the right of this threshold signal the risk of neglected profits.

The three thresholds bound a decision region associated with the action of monitoring information. Events that fall in this region trigger the default action: don't trade, hold the position, and focus attention on market events. If a trader is responsible for more than one position, events that place one currency in this region are likely to lead her to shift attention to another currency.

Experiment

The decision making task studied in the experiment is trading in the spot (delivery in three days) foreign exchange markets. Three traders from the foreign exchange department of a large customer-oriented Twin Cities bank agreed to serve as subjects. Subjects have four to twelve years experience at the trading desk and are responsible for their bank's exposure to foreign currencies. Their task in the experiment is to generate "profits" by trading a pair of currencies simultaneously as a market scenario unfolds. The illusory nature of these profits is likely to be the most serious constraint to the generality of the experimental results.

Eight trading scenarios were constructed. Each scenario presents a realistic but hypothetical global socioeconomic setting based on historical precedent. During each scenario, market events - news and price changes - unfold as they do on the traders' job. The platform for experimentation that simulates their work environment is Treasury Risk Manager (© 1987-92 Chisholm Roth & Co Ltd), a commercial PC-based training package that emulates the Reuters on-line foreign exchange dealing screen. While Treasury Risk Manager simulates spot, forward, and money markets, this research focuses on spot markets where traders routinely encounter time pressure. The scenarios were presented to subjects individually in random order over two to four days.

Measures and apparatus

We gather two types of data to ascertain how traders think about the risks associated with foreign exchange. Videotape recordings and concurrent verbal reports (protocols) reveal overt decision making behavior. This behavior includes shifting the focus of attention among several information displays, answering telephone requests to quote prices (quoting), contacting other traders to ask them to quote prices (dealing), and executing trades. The salient measure of overt behavior is profit or loss.

Spectral analysis of heart-rate variability reveals a covert aspect of risky decision making: the level of cognitive effort (Kahneman, 1973; Vicente, Thornton, & Moray,1987). The amplitude of the 0.10 Hz component of the power density spectrum of the heart-beat interval time series is inversely proportional to the on-going level of cognitive effort (Mulder, 1980). The amplitude of the power spectrum at a given frequency is directly proportional to variance - amount of information - in the time series at that frequency (Bingham, Godfrey, & Tukey, 1967). These complementary lines of evidence test the explanatory power of the phase plane construct. We calculate an index of cognitive effort by subtracting the total estimate of variance between 0.07 and 0.14 Hz from an arbitrary large number.

We assume that an increase in the index of effort in the absence of physical exertion or other sources of stress reflects an increase in cognitive effort. While these conditions are met in our experiments, spectral analysis of cardiac arrhythmia is currently a

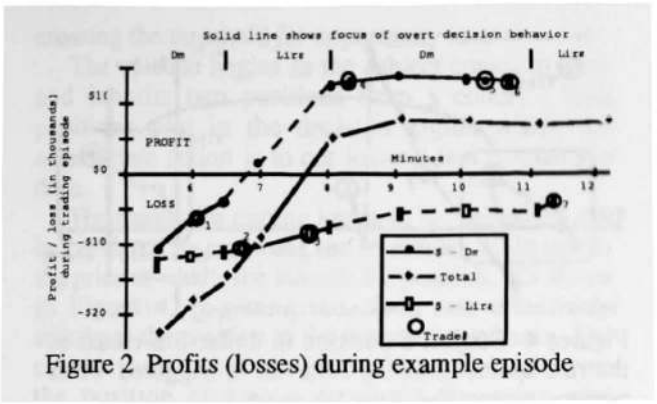


Figure 2 Profits (losses) during example episode

controversial index of cognitive effort (Hancock, Meshkati, & Robertson, 1985).

Results

We present an episode from one experimental session to illustrate our understanding of how professional foreign exchange traders allocate effort as they make risky decisions. There are typically three or four such episodes in each session. In this scenario the subject is responsible for positions in both the German mark (Dm) and the Italian lira (L); she has "inherited" two losing positions from a cohort: long $8 (million) against marks and long $7 against lira. The dollar-lira position starts further out of the money than the dollar-mark position. Figure 2 tracks her profits and losses during the episode. Trades are numbered and highlighted with open circles.

Figure 3 traces the index of cognitive effort during the episode. Estimates of the relative amount of effort the subject expends during 40 second intervals are calculated every 20 seconds and plotted midway through the interval. We analyze the graph for trends in the level of effort, not for single point anomalies. Trades are again highlighted with open circles. Text below the effort trace highlights market events that appear to drive the subject's decision making behavior. Text near the trace summarizes the actions she takes.

We begin with a review of the effort and profit data. We then offer an explanation of her decision making behavior by recasting the decision variables in the phase plane.

Effort and decision making

In the five minutes prior to this episode, the subject reads an "overnight report" like that she gets every morning at work. This summary of global socioeconomic conditions and events suggests that the market expects the dollar to be relatively strong against the lira and weak against the mark. The

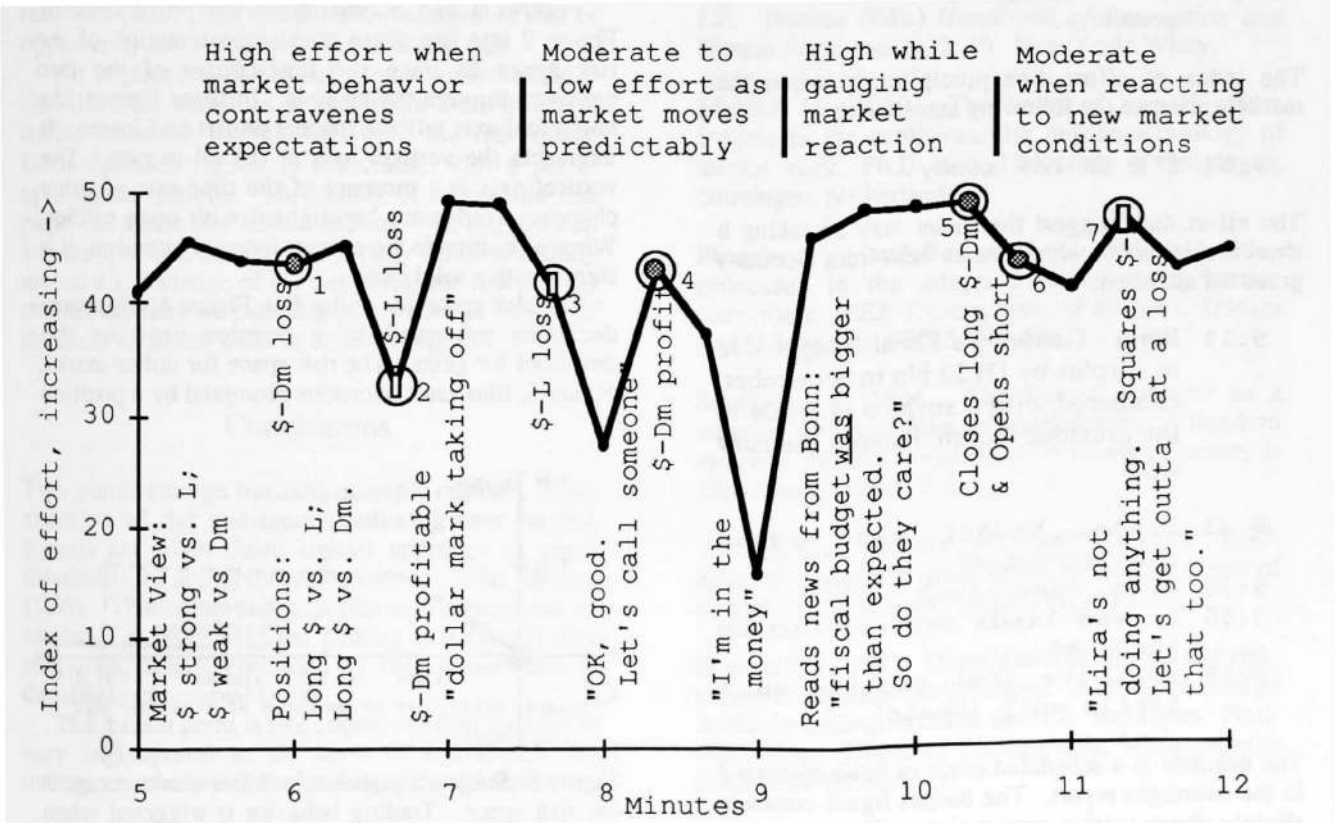


Figure 3 Time trace of cognitive effort during example episode

prevailing wisdom leads her to be more concerned with her dollar-mark position than her dollar-lira position.

The subject faces the risk of paper losses in both positions. Her first act is to trim her long dollar-mark position, taking a small loss in the process. At six minutes into the session, the dollar unexpectedly rallies against the mark while remaining relatively weak against the lira. This price movement prompts the following line of protocol:

6:14 Dollar mark kinda rocketing here. What was the news?

As shown in Figure 3, the subject responds with a relatively high level of effort. Effort remains high even after the dollar-mark position turns profitable.

By 7:30 (minutes), it becomes clear that the dollar is rallying:

7:26 Dollar marks taking off

Her level of effort moderates as she takes stock of her positions and the effects of her actions. She has slashed the unprofitable dollar-lira position and held most of the profitable dollar-mark position.

7:59 So now I'm long 1 against lira ... Plus 1 (L) plus 5 (Dm) OK good ... Lets call someone.

The index of effort dips precipitously when the markets provoke the following assessment:

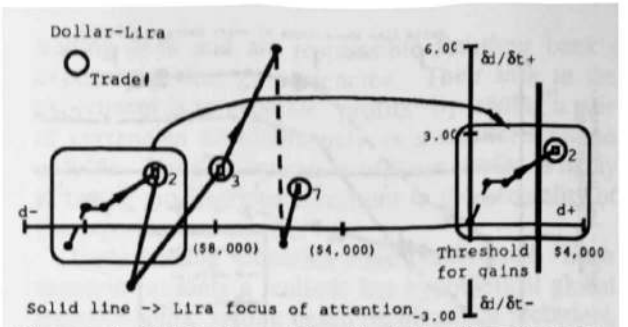
9:04 I'm in the money.

The effort data suggest the trader may be taking a short mental break when a news item from Germany grabs her attention:

9:19 Bonn - Germany's Fiscal Budget was in surplus by D1.23 bln in September, compared with a surplus of D1.04 in the previous month, Finance Ministry said.

9.23 fiscal budget was bigger than expected
9:30 so do they care?
9:50 It was kinda expected to be there so
9:55 well its (Dm) picking up a little well [Deals]

The headline is a scheduled piece of news discussed in the overnight report. The budget figure comes in slightly above market expectations. This news may



Figures 4 Subject's position in dollar-lira recast in the risk space. Trading behavior is triggered when position crosses threshold for gains.

be bearish for the dollar. The subject faces a quandary. Is the market going to move on the news against her profitable dollar-mark position? Her response to the headline is a high level of effort as she focuses on her dealing screen to track the rate of movement in the mark. When she sees that the mark is "picking up" - moving against the dollar - she calls out to take profits. She executes a pair of trades that yield substantial profits. Effort moderates. It is relatively easy to take profits in predictable markets, even when they are predictably contrary.

The risk space

Figures 4 and 5 transforms the profit data of Figure 2 into the phase plane representation of the risk space to trace the time-course of the two positions through the episode. In these figures, the horizontal axis reflects (paper) profits and losses. It intersects the vertical axis at the all-in rate. The vertical axis is a measure of the time rate of price change. Trades are highlighted with open circles. When a position is the current focus of attention, it is shown with a solid line.

The risk space for dollar-lira, Figure 4, illustrates decisions prompted by a position crossing the threshold for gains. The risk space for dollar-marks, Figure 5, illustrates decisions prompted by a position

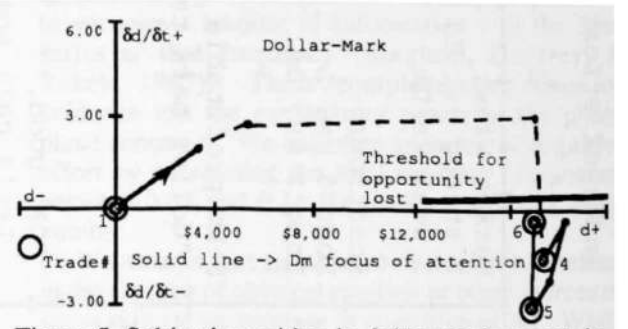


Figure 5 Subject's position in dollar-marks recast in the risk space. Trading behavior is triggered when position crosses threshold of opportunity lost.

crossing the threshold for opportunity lost.

The episode begins as the subject comes to work and inherits two positions from a cohort. Both positions plot in the decision region where the appropriate action is to cut losses; this is what she does.

The timing for cutting losses in the dollar-lira can be predicted by assuming she re-sets her all-in rate to the price at which she inherits the position. As shown in Figure 4, re-setting the all-in rate effectively translates the position to the intersection of axes. She cuts her losses as if she were taking gains wherever the position crosses a threshold for gains near +$2500. Later, when queried about this type of behavior, the subject said "I really started at zero since this was an overnight position". She manages foregone losses as if she were capturing gains.

This episode provides no evidence for a threshold for gains in the dollar-mark. Rather, she allows the dollar-mark to appreciate as she cuts her losses in the dollar-lira. Managing foregone losses is more pressing than taking certain profits.

She shifts attention to the dollar-mark when the rate of change of the dollar-mark price turns negative. This turn from rising to falling prices is reflected in the risk space by an abrupt drop below the horizontal axis. The subject takes profits as the position closes in on the horizontal axis, that is, just before the rate of change can be predicted to turn from positive to negative. She acts just before it appears the mark will reach its peak. Her threshold for acceptable risk of opportunity lost lies above the horizontal axis.

An implication of the risk space representation is that decision variables in the trader's environment define coherent regions of within the risk space. Each decision region is associated with a set of appropriate actions. Thresholds of acceptable risk parse the space and isolate actions. We suggest that key components of expertise at risky decision making are tacit knowledge of (1) thresholds for risk and (2) the dimensions of risk that place current values of decision variables within a decision region.

Conclusions

Two points emerge from the example episode. First, experienced risk managers monitoring time-varying signals act when those signals approach or cross thresholds for acceptable risk (Senders, 1966; Moray, 1986). This result suggests that one component of expertise at risky decision making is judgment that compares signals generated by the environment to thresholds of acceptable risk.

The second point is that cognitive effort appears to vary in response to the level of confidence the manager has in her understanding of the environment. The index of cognitive effort may provide insight into decision making about uncertainty.

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