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# THE SENSITIVITY OF SENSITIVITY: HAZARDS OF SOFTWARE-BASED FINANCIAL DECISION MAKING

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# THE SENSITIVITY OF SENSITIVITY: HAZARDS OF SOFTWARE-BASED FINANCIAL DECISION MAKING

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## Abstract

*Retail individual investors are increasingly being targeted with complex investment products based on derivatives. Such investors, with their limited knowledge of finance, might not fully appreciate the variability of returns associated with so-called structured products. Sensitivity analysis is often recommended as a way for investors to explore the variability of returns and thus make better informed investment decisions. Through sensitivity analysis, investors are expected to assess investment products by examining them under different scenarios depicting the uncertain conditions that affect the returns from these products. However, a sensitivity analysis is only as valuable as the ranges over which such analysis is conducted. The theory of framing in behavioral decision theory suggests that the range employed for sensitivity analysis can significantly influence an investor's assessment of a financial product.*

*In this paper, we report the results of an experiment where two groups of subjects were exposed to an investment product linked to movements in the inter-bank interest rate. Subjects were instructed to carry out sensitivity analyses with respect to this rate using Microsoft Excel. The two groups faced identical experimental stimuli except for a single difference: they conducted their sensitivity analyses over different ranges of the inter-bank interest rate. As the theory of framing predicts, the same investment product was viewed differently by the two groups. Our results suggest that the range over which sensitivity analysis is conducted can be manipulated to influence how an investment product is perceived, thus undermining the efficacy of such analysis. When this happens, private investors unfamiliar with investment products run the risk of making inappropriate investment decisions with the potential for significant personal and social costs.*

**Keywords:** Decision support systems, decision-making, lab experiment

## Introduction

In the past, derivatives (i.e., contracts whose payouts are tied to the behavior of interest rates, stock market indices, or the prices of other assets) were used mainly to hedge organizations' and individuals' exposure to the fluctuating prices of goods and services. In recent times, however, derivative contracts are increasingly marketed as investment products for those seeking high rates of return. These high rates of return carry commensurate risk. Furthermore, one emerging market for derivatives is the private individual investor, who has limited knowledge of finance. There is concern that some investors might end up investing their savings in products whose characteristics (e.g., volatility, and the potential for downside losses) they do not fully understand.

Derivative contracts are highly complex. To market these products, sellers often employ financial software such as spreadsheets to demonstrate how the derivative works. As part of the description of the product, the seller might conduct sensitivity analysis, i.e., demonstrate the derivative payouts under different scenarios with e.g., varying interest rates. The theory of framing predicts that sellers can manipulate the sensitivity analysis to position their

derivative instruments in a manner that misrepresents the true characteristics of the instrument. In the context of sensitivity analysis, the different ranges over which the analysis is conducted can act as separate frames, and the investor's evaluation of the same investment product might be colored by which frame the investor is exposed to.

The objective of this paper is to determine whether software-supported sensitivity analysis is subject to framing effects. The contribution of this paper is to demonstrate that software-supported sensitivity analysis can be used to manipulate investors' perceptions of a particular investment product. Our findings suggest that sellers can influence investors' assessments of financial products through apparently "rigorous" sensitivity analyses over inappropriate ranges. We suggest that it might not be sufficient for regulators to merely mandate the use of sensitivity analysis to show the robustness of financial products to potential investors. In addition to the requirement for sensitivity analysis, there might be a need for explicit guidance about the appropriate ranges for such sensitivity analyses.

The rest of this paper is organized as follows. We begin with a quick review of the literature on sensitivity analysis, spreadsheet software and framing, especially as they relate to financial decisions. Following this, we describe our experimental context, the decision-making task, and our research hypotheses. After we present our experimental findings, we end with a discussion of the implications of this research, especially for public policy.

## **Related Research**

Traditional thinking holds that a potential investor can improve his or her understanding of an investment product by exploring its returns under different scenarios. Such investigation, commonly termed sensitivity analysis, is especially helpful in showing investors how their investment returns would change as a result of projected movement in the underlying indices, rates, or prices. Thus, a product whose returns are related to inter-bank interest rates is better understood if the investor observes the variability of returns under different interest rate scenarios. Similarly, the decision to invest in a product whose value is tied to foreign exchange rates should take into account the returns expected under different scenarios of relative currency appreciation and depreciation.

Numerous institutions and academics recommend the use of sensitivity analysis to examine the variability of returns from derivative investments (Federal Deposit Insurance Corporation, 1998; Hodder and McAnally, 2001). The financial reports of many large corporations now follow this advice, and routinely carry sensitivity analyses of their derivative investments. For example, IBM's 2004 annual report states:

*"At December 31, 2004, a 10 percent decrease in the levels of interest rates with all other variables held constant would result in a decrease in the fair market value of the company's financial instruments of \$172 million as compared with a decrease of \$170 million at December 31, 2003. A 10 percent increase in the levels of interest rates with all other variables held constant would result in an increase in the fair value of the company's financial instruments of \$153 million as compared to \$152 million at December 31, 2003."*

Similarly, Verizon's 2004 annual report states:

*"The table that follows summarizes the fair values of our long-term debt and interest rate derivatives as of December 31, 2004 and 2003. The table also provides a sensitivity analysis of the estimated fair values of these financial instruments assuming 100-basis-point upward and downward parallel shifts in the yield curve. Our sensitivity analysis did not include the fair values of our commercial paper and bank loans because they are not significantly affected by changes in market interest rates."*

## **Financial Analysis Software**

Spreadsheets are among the most pervasive forms of software. Modern releases of spreadsheet software include built-in functions for sensitivity analysis over what-if scenarios (Mather, 1999; Morgan and Henrion, 1990). As a result, individual investors have begun to perform such analyses on their investment instruments (Croskey, 1988). Commenting on 25 years of spreadsheet usage, Baker & Sugden (2005) observe

*"In hindsight it seems obvious, but probably one of the most profound, clear benefits of using spreadsheets that emerges from this study is just that of saving time. The time gained can then be spent on investigating properties of the mathematical objects created in the spreadsheet environment: the so-called what-if scenarios. There is huge scope for investigation of dependence on parameters in almost any spreadsheet model of a mathematical process."*

Responding to investors' preference for sensitivity analysis, sellers of financial products often use software to present various scenarios to potential customers as part of their sales pitch. Software companies have arisen to develop software for explicit use as marketing tools for financial products. For example, Torrid Technologies sells software specifically geared to financial salespeople selling to private investors. The blurb on their website claims:

*Retirement Savings Planner - Professional Edition software: This Quick, Simple, and Visual software can be used to create colorful illustrations that captivate your clients, build rapport, and enhance your sales efforts. This boosts your skills in selling Life Insurance, LTCi, Annuities, Reverse Mortgages, Disability, wealth management, or any other related financial product.*

([http://www.torrid-tech.com/rp\\_main\\_pro.html](http://www.torrid-tech.com/rp_main_pro.html))

Considering that spreadsheets are one of the top two information systems in terms of deployment in organizations (CFO.com survey, 2004; the other contender is ERP systems), relatively little IS research targets spreadsheet use and consequences. Most of the extant IS research into the use of spreadsheets focuses on identifying and auditing errors in spreadsheets used to inform decisions in organizations (Panko, 2005). In contrast, our study relates to the use of spreadsheets by individuals acting in their personal capacity. In our study, there are no errors in the implementation of the spreadsheet models; rather it is the seemingly "correct" use of sensitivity analysis that distorts the decision making of our experimental subjects.

### **Framing**

The use of spreadsheet software for financial analysis can be viewed in at least two ways. First, such software can be viewed as an aid to assist investors to assess the characteristics of investments. Second, sensitivity analysis may itself be susceptible to framing and spreadsheet software allows financial salespeople to create misleading frames. Given the widely favorable assessment of spreadsheet software for decision support, this research takes the alternative (i.e. second) view of spreadsheet software.

Framing describes situations where the way information is presented leads individuals to make divergent choices (Kahneman, 2003). In their seminal paper on the framing of decisions, Tversky and Kahneman (1981) demonstrated that individuals would adopt distinct strategies to a disease outbreak problem depending on whether they were told individuals would die or be saved. In the positively framed version of the problem, a clear majority of respondents preferred saving 200 lives for sure (72%), over the option that offered a 1/3 chance of saving 600 lives (28%). In the negatively framed version, most people preferred the 1/3 chance of losing no lives (78%) to the sure loss of 200 lives (22%). From a probabilistic "expected-value" perspective, the two situations are identical, and the difference in subjects' responses is attributed to the difference between the positive and negative frames.

Following this elegant demonstration, the literature on framing has grown explosively. Two influential reviews of framing effects by Levin et al (1998) and Kuhberger (1998), between them, synthesized over 300 studies. Today, studies of framing are found in almost all aspects of human decision-making, including medicine (McGettigan, et al., 1999), capital markets (Kent, et al., 2002), and ethical reasoning (Bateman, et al., 2001).

In choosing an investment product, sensitivity analysis requires an investor to identify a range of potential future conditions and the returns accruing to the investment under each of these conditions. Uncertainty in these future conditions makes the return on the investment uncertain. The presence of uncertainty is what makes the sensitivity analysis of derivative products amenable to framing: the seller can influence or constrain the range of conditions over which the investment is examined. Different choices of the range of sensitivity analysis correspond to different frames, some of which make a product "look good." Hence our research question:

*Can the range of the sensitivity analysis presented through spreadsheet software influence the decisions of naïve investors?*

### **Methodology**

To test if naïve investors suffered framing effects when they perform sensitivity analysis using spreadsheet software, we conducted an experiment on 152 accounting and business freshmen at a university. Freshman accounting and business students at this university are excellent proxies for naïve investors. Accounting and business freshmen at this university take identical courses, and have no opportunity to take financial courses. Finance is taught in their

second year. However, as accounting and business students, these individuals demonstrate a clear interest in business and financial matters.

The experiment was conducted in four classes of an introduction to IT course. In the course, subjects were instructed in the use of a spreadsheet tool to perform sensitivity analysis. The students were assigned the task of deciding between two investment alternatives (investment product A and B). Investment product A was based on the following (real) product offered by a bank in 2004:

- The duration of the investment is 4 years (early withdrawal entails significant penalty).
- For the first year, the deposit earns 3% simple interest.
- In the second, third, and fourth year, the deposit earns simple interest at the following rate:  
 $2 \times \text{Rate of interest paid in the previous period} - \text{Current inter-bank rate}$
- Interest is calculated semi-annually.

Investment product B, a floating-rate deposit, earned compound interest at the rate of 75% of the prevailing inter-bank rate, compounded semi-annually. All subjects assessed the *same* pair of investment products, indicating their relative preference for the two products by allocating a total of \$50,000 across the two products. Subjects were also asked to explain their decision.

The experimental manipulation was as follows. 74 subjects (two classes) were instructed to investigate the sensitivity of investment returns of product A assuming an initial inter-bank rate (henceforth IBR) of 1% rising sharply at a rate between 31% and 52% in each half-year period (the sharp-rise scenario). The remaining 78 subjects (two classes) investigated the sensitivity of the same investment product A using a starting IBR of 2% rising gradually at a rate between 11% and 18% per half-year (the slow-rise scenario). Both sets of scenarios were comparable and realistic for a time when interest rates were coming off record lows. Also, neither scenario manipulated the (real) investment instrument. A rational investor (i.e., one not affected by framing) should behave identically under the two scenarios. Figure 1 below shows the results of the sensitivity analysis for the sharp-rise treatment group. SD refers to the structured deposit (product A), and FD to the floating-rate deposit (product B).

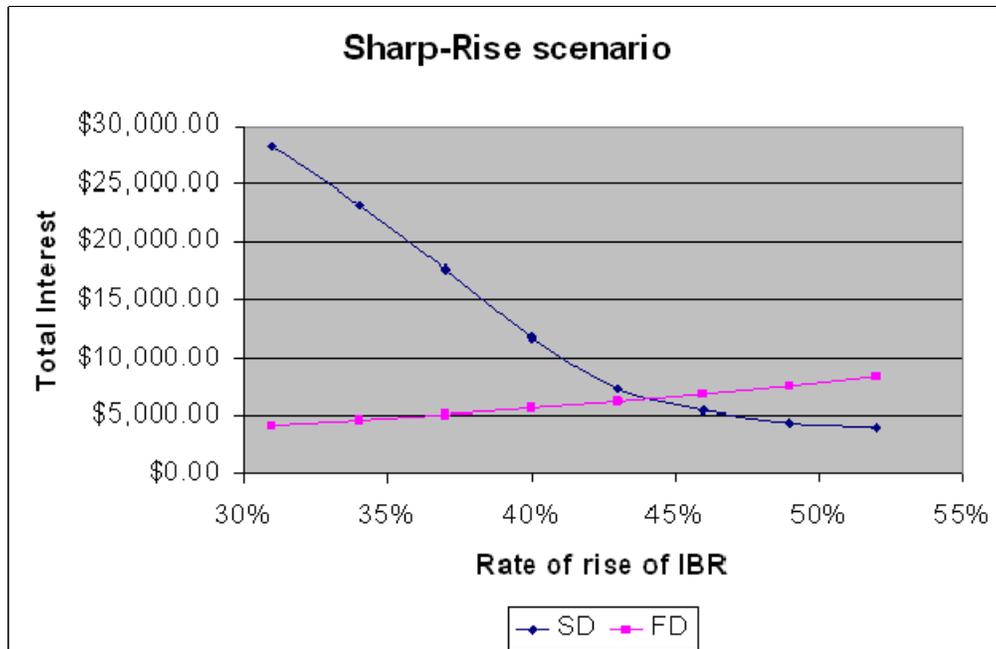
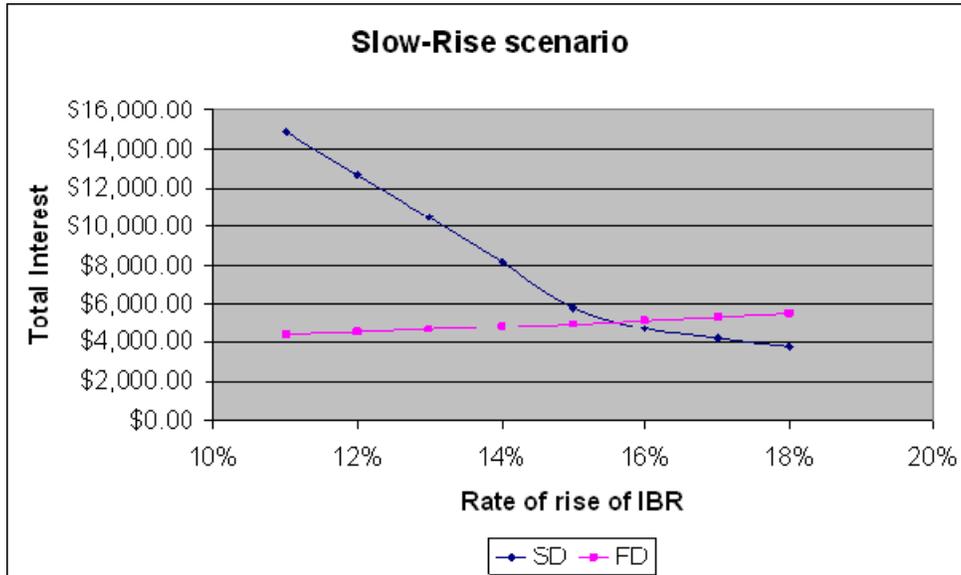


Figure 1: Sensitivity analysis for the Sharp-Rise scenario

The structured deposit (product A) earns more interest than the floating-rate deposit (FD) for about two-thirds of the range of IBR growth rates.

Figure 2 shows the sensitivity analysis for the slow-rise scenario. As in the sharp-rise scenario, in the slow-rise scenario the structured deposit (product A) dominates the floating-rate deposit (product B) over two-thirds of the range of IBR growth rates. However, the variance in the difference is not as large as in the Sharp-Rise scenario.



**Figure 2: Sensitivity analysis for the Slow-Rise scenario**

The Sharp-Rise scenario emphasizes the variability of investment returns with IBR growth rates, and to that extent constitutes a “risky” frame around the investment product. In contrast, the Slow-Rise scenario understates this variability, emphasizing instead the superiority of returns relative to the fixed deposit.

Because subjects performed their own sensitivity analysis, the researchers did not manipulate the way graphs were formatted, sized, etc. Subjects worked through all the steps of the Excel exercise by themselves. Issues related to the presentation of data to subjects were thus avoided as potentially confounding factors. We would like to highlight that our experimental task provided subjects the opportunity to engage “actively” in sensitivity analysis, in the sense that they themselves constructed the spreadsheet to perform the analysis. This is different from passive “recipients” of sensitivity analysis, who receive the results of analysis conducted by someone else. Thus, we feel that our subjects had a good opportunity to “experience” the two products first-hand, better than the exposure to canned results would have provided. If in spite of this, our subjects fall victims to framing, consider the situation of those whose experience of sensitivity analysis is more distant (reading a set of results reported by someone else).

The literature suggests that investors’ risk preference (Engle, 2003) and gender strongly influence their investment choices, with women thought to be more risk-averse than men (Byrnes, et al., 1999). The university’s accounting program is also substantially more competitive than its business program, and thus the accounting and business students could exhibit differences. Business students at this university only select their specialization in their second year. Most business students at this university elect to specialize in banking and finance. We therefore included risk preference, gender, and major as control variables. Risk preference was measured using a single-item measure. We did review various multi-item measures of risk preference, but many such as that of Weber et al (2002), required subjects to answer questions relating to investments in government bonds, growth stocks and speculative stocks. Such risk instruments were clearly inappropriate for our subjects, and perhaps not applicable to naïve investors either. Gender and major were measured dichotomously (i.e., 0 for male and accounting, 1 for female and business).

As this was an in-class exercise, we had no non-respondents. Ethically, students were not harmed in any way. The in-class assignment focused on students’ mastery of Excel functions such as scenario analysis. As the sole manipulation altered the ranges for the sensitivity analysis, neither group of students required or received preferential instruction. Students were also not penalized for an “incorrect” answer.

Treatments were administered to students via a tutorial written in Microsoft Word. Students could either view the tutorial online or print it out. The two versions of the tutorial differed only in terms of the experimental

manipulation. Researchers did not intervene during the course of the experiment except to answer technical questions about how Excel works. When students asked researchers for the correct answer, they were informed that there was none. They were also told that Excel, as a decision support tool, would only organize already available information to facilitate decision making.

## Data Analysis

We conducted an OLS regression of our data. The dependent variable is the share of the \$50,000 allocated to the structured deposit, product A. The regression was significant ( $R^2 = 0.263$ ,  $F = 11.232$ ,  $df = 130$ ,  $p < 0.001$ ). Findings are summarized in Table 1.

**Table 1: Regression of amount invested in structured product on frame, risk attitude, major and gender**

| Variable                       | Beta      | Std. Beta | t      | p-value | Interpretation  |
|--------------------------------|-----------|-----------|--------|---------|---|
| Experimental manipulation      | 6481.901  | 0.207     | 2.688  | 0.008   | Range of sensitivity analysis values influences decision of naïve investor  |
| Risk attitude                  | 7993.755  | 0.468     | 6.056  | <0.001  | Risk attitude influences decision of naïve investor                         |
| Major (accounting or business) | -540.121  | -0.17     | -0.223 | 0.824   | No evidence that major field of study influences decision of naïve investor |
| Gender                         | -1736.286 | -0.052    | -0.670 | 0.979   | No evidence that gender influences decision of naïve investor               |

The range of sensitivity analysis has a significant effect on the investment decision of naïve investors. The slow-rise group of subjects allocated *more* funds to product A, perceiving it as less risky than the sharp-rise group. Also, individuals with greater risk appetite allocated more funds to product A. Gender and major did not have significant effects on the investment decisions of our subjects.

Some of the qualitative comments collected from the subjects were illuminating. Subjects from the sharp-rise group made statements like:

*“I will invest \$0 in the Structured Deposit and \$50,000 in the Fixed Deposit. Although initially the interest earned from structured deposit is high compared to fixed deposit, the graph has a downward sloping pattern while fixed deposit is upwards sloping and is more stable. I will put all my money into the fixed deposit.”*

and

*“I will invest \$10000 in the structured deposit and \$40000 in the fixed deposit. This is because the risk involved in investing in the fixed deposit is much less than that of the structured deposit as seen from the graph where the graph of the structured deposit varies with a steep gradient while the fixed deposit curve has a gentle gradient. Thus in the long run, it is safer to invest more in the fixed deposit.”*

Typical statements from the slow-rise group included:

*“I would invest all \$50000 in the structured deposit as it offers higher interest rate.”*

and

*“I will invest S\$40,000 dollars in the structured deposit and S\$10,000 dollars in the fixed deposit. According to the graph, the change in the fixed interest rate is slow and gradual. Although this seems like a safer option, the rate of return is lower, compared to that of the structured deposit. Hence, I would invest more in the form of structured deposit.”*

It is interesting that both sets of comments apply to the *same* investment products A and B. The framing effect (sharp-rise = high variability and slow-rise = low variability) is very visible in the qualitative data.

Our findings mirror the strong preference for assets with steady (as opposed to volatile) prices that Clark-Murphy and Soutar (2004) found among Australian investors. In some ways, our work also parallels that of Diacon and Hasseldine (2005) who found that longer time series of mutual fund performance data heightened the perception of risk by subjects compared to shorter data series for the same funds.

## Discussion and Conclusion

It is often assumed that sensitivity analysis over a range of scenarios, facilitated by spreadsheet software, can “expose” the variability of returns from investment products. While this is true at one level, the actual ranges over which such analysis is carried out appears to have significant potential for framing products as risky/aggressive vs. stable/conservative. In our experiment, the subjects had the opportunity to conduct their own sensitivity analysis using spreadsheet software. In most real-life settings, potential investors receive canned outputs of such analysis in the form of a product demonstration or a marketing brochure. In such cases, it is tedious, if not impossible to alter the range of sensitivity analysis even if the investor “smells a rat” or is just plain curious. For a seller of financial products, it is tempting to cherry-pick scenarios that make products look better.

International changes in business practices have forced more individuals to take personal responsibility in how their retirement funds are invested. Many pension plans have been changed from defined-benefit to defined-contribution, i.e., pension plans no longer guarantee a sum of money upon maturity. At the same time, banks and financial institutions in North America, Europe, and Asia are shifting out of conventional time deposits, and actively promoting structured products and other derivatives. Only a small proportion of investors in this decade have the deep knowledge of finance needed to choose wisely among the plethora of such investment products. To make matters worse, a significant proportion of them might not allocate much effort to these decisions. For example, 58% of Benartzi & Thaler’s (1999) respondents spent one hour or less on choosing appropriate investments for their retirement funds. Financial salespeople are also increasingly aware of heuristics and biases and how to exploit these characteristics of human decision-making (Jordan and Klaus, 2002). Finally, financial salespeople have increasingly sophisticated technology to help them sell their wares. As a result of all these, it is possible that individual investors might misjudge the variability of returns from complex investment products, and enter into investments that they subsequently regret. The personal and social costs of such actions are potentially severe.

At first sight, sensitivity analysis promises to reveal the “true” variability of investments to such investors. Indeed regulators have frequently suggested (and even required) sensitivity analyses for derivative products. They have also sometimes required that sellers of investment products display the results of sensitivity analyses for investors to gain a sense of the variability of expected returns. However our study suggests that this alone might be insufficient, as it is still possible for sellers to choose the range of sensitivity analysis so as to influence investor decision-making. Unethical sellers can manipulate the range of sensitivity analysis to mislead potential buyers about the characteristics of investment products. To guard against this, the requirement to conduct sensitivity analysis might need to be augmented with guidance about the appropriate *ranges* for such sensitivity analyses.

The experiment described in this paper is part of a broader stream of research into a variety of investment products and investor populations. We suspect that framing effects are fairly ubiquitous for complex products. If this is indeed true, we hope to contribute to the debate on whether regulators should demand more disclosure and transparency for such financial products sold to retail investors.

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