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Behavioral bias in number processing: Evidence from analysts' expectations☆

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ABSTRACT

Research in neuropsychology shows that individuals process small and large numbers differently. Small numbers are processed on a linear scale, while large numbers are processed on a logarithmic scale. In this paper, we show that financial analysts process small prices and large prices differently. When they are optimistic (pessimistic), analysts issue more optimistic (pessimistic) target prices for small price stocks than for large price stocks. Our results are robust when controlling for the usual risk factors such as size, book-to-market, momentum, profitability and investments. They are also robust when we control for firm and analyst characteristics, or for other biases such as the 52-week high bias, the preference for lottery-type stocks and positive skewness, and the analyst tendency to round numbers. Finally, we show that analysts become more optimistic after stock splits. Overall, our results suggest that a deeply-rooted behavioral bias in number processing drives analysts' return expectations.

1. Introduction

Sell-side analysts produce diverse information in their research reports: stock recommendations, earnings (or cash-flow) forecasts, target prices, and some justifications or explanations (Asquith et al., 2005; Bradshaw et al., 2013). It is well-documented that earnings forecasts and target prices are biased (Bradshaw et al., 2014; Ramnath et al., 2008). Financial

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analysts are optimistic: earnings forecasts are frequently higher than realized earnings, and target prices tend to be greater than current prices. For instance, Brav and Lehavy (2003) find an average return implied by target prices of 28% for the 1997–1999 period, while Bradshaw et al. (2013) report an implied return of 24% for the 2000–2009 period. These implied returns greatly exceed realized market returns over the same periods.

Explanations for this optimism bias principally come from two streams of research. In the first stream of research, financial analysts are viewed as rational economic agents and their optimism reflects their incentives to produce inaccurate figures (Bradshaw et al., 2014; Lim, 2001; Mehran and Stulz, 2007). In the second stream of research, financial analysts are characterized by some behavioral biases. The use of specific heuristics leads analysts to miscalculate (Cen et al., 2013; Clarkson et al., 2013).

In this paper, we contribute to the latter stream of research by showing that analysts process small numbers (*i.e.*, small stock prices) differently from large numbers (*i.e.*, large stock prices). They exhibit a specific behavioral bias, which we call the small price bias, when issuing target prices. This bias leads analysts to produce bolder forecasts for small price stocks than for large price stocks. Since analysts tend to issue optimistic target prices (*i.e.*, target prices with positive implied returns), they are, on average, more optimistic on small price stocks than on large price stocks. However, for the minority of pessimistic target prices (about 13%), analysts are more pessimistic on small price stocks than on large price stocks. Working with analysts' target prices allows us to directly test the small price bias on individuals' expectations.[1]

Our argument for the existence of a small price bias is grounded in recent research in neuropsychology, where the mental representation of numbers has been extensively studied (Dehaene, 2011, for a review). The human brain processes numbers on a mental number line, that is, a spatial representation of numbers. The mapping between a number and its spatial position on the line, however, is not linear.

When evaluating proximity relations between numbers, people exhibit two common characteristics (Dehaene et al., 1998; Nieder, 2005). First, when people rank numbers, the reaction time and the error rate are a decreasing function of the difference between the two numbers. This first characteristic is called the distance effect. For instance, it is faster to recognize that 10 is greater than 1 than to perceive that 6 is greater than 5. The second characteristic is called the size effect. For a given difference between two numbers, people are slower in deciding, for instance, that 35 is greater than 34, than in deciding that 6 is greater than 5. The quantitative model of the distance effect and the size effect is known as Weber's law. In short, Weber's law states that numbers are measured on a logarithmic scale in the brain (Nieder, 2005): increasingly larger numbers are subjectively closer together.

Dehaene et al. (2008) and Hyde and Spelke (2009), however, show that deviations from the logarithmic scale are observed for small numbers, in particular, as a result of formal education. Hyde and Spelke (2009) argue that “Despite many years of experience with symbolic systems that apply equally to all numbers, adults spontaneously process small and large numbers differently. They appear to treat small number arrays as individual objects to be tracked through space and time, and large-number arrays as cardinal values to be compared and manipulated” (p. 1039).

People tend to use a linear scale for small numbers and a logarithmic scale for large numbers.[2] This linear scale for small numbers implies that people are able to correctly evaluate absolute distances between small numbers. The use of a logarithmic scale for large numbers, however, leads to a compressed mental number line. People underrepresent absolute distances between large numbers. A corollary can be derived for relative distances. Relative distances between large numbers are correctly assessed (as a result of the use of a logarithmic scale) while relative distances between small numbers are exaggerated. Since the norm in finance is to work with relative distances (*i.e.*, stock returns), we expect market participants to incorrectly process small prices. The linear scale corresponds to a slope equal to ± 1 on the mental number line and the logarithmic scale to a slope lower than 1 in absolute value. We thus expect the use of a linear scale to lead to bolder forecasts for small price stocks.[3]

These arguments allow us to formulate the following hypothesis: if analysts use a linear scale for small price stocks and a logarithmic scale for large price stocks, optimistic (pessimistic) target prices will be more optimistic (pessimistic) for small price stocks than for large price stocks.

To test this hypothesis, we use a sample of 814,117 target prices issued by 9141 analysts on 6423 U.S. stocks, over a fourteen year period (2000–2013). We find that analysts issue bolder forecasts on small price stocks than on large price stocks. We use target price implied returns as an *ex-ante* measure of optimism (pessimism). We also measure optimism (pessimism) *ex-post* by using signed forecast errors. Implied returns are computed by comparing target prices to current stock prices while signed forecast errors are obtained by comparing target prices to future (realized) prices. Over the whole sample period, the average implied return[4] of optimistic (pessimistic) target prices issued on stocks with a nominal stock price below \$10, is about 39% (−10%). The corresponding figure for stocks with prices above \$40 is approximately 19% (−8%).

Since stock prices and market capitalization (firm size) are positively correlated (Baker et al., 2009), we ensure that our results are not driven by a size effect. To disentangle the small price bias from a potential size effect, we double sort

[1] Target prices provide more relevant information to investors than earnings (or cash-flow) forecasts or even stock recommendations (Bradshaw, 2011). In addition, Brav and Lehavy (2003) show that market participants react to information contained in target prices.

[2] Even if formal education is supposed to induce the use of a linear scale, Dehaene et al. (2008) and Viarouge et al. (2010) conclude that “a logarithmic representation may remain dormant in all of us for large numbers”.

[3] The derivative of $f(x) = ln(x)$ is $1/x$ which is lower than 1 for $x > 1$.

[4] Implied return is defined as the difference between the target price and the current stock price scaled by the current price.